**Abstract**

EFFECTS OF A BEFORE SCHOOL PHYSICAL ACTIVITY PROGRAM ON PHYSICAL ACTIVITY, MUSCULOSKELETAL FITNESS, AND COGNITIVE FUNCTION IN THIRD-GRADE CHILDREN

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Regular physical activity is important for everybody, but may be especially beneficial for children. Despite this, most children in the United States do not meet physical activity recommendations. Schools are a prime location for targeting the physical activity levels of children given their ability to reach many children in one accessible and safe location. Unfortunately, schools provide limited opportunities for children to be active during the school day as pressures increase to focus more on academic work. Cutting physical activity time during the school day may have a negative impact on children's physical and mental health.

**Purpose:** The purpose of this study was to evaluate the effects of a simple, low-cost physical activity program before school on third-grade children's physical activity levels, musculoskeletal fitness, and cognitive function. **Methods:** Physical activity was measured daily at the 10-week program using pedometers. Physical activity during the school day was measured by accelerometers for one week while the program was in session and for one week after the program ended. Musculoskeletal fitness was measured using four tests during early and late intervention. Cognitive function was assessed at the beginning of the program on a day children did not attend the before-school activity program, and near the end of the program on a day children spent at least 10 minutes engaged in physical activity at the program. **Results:** Twenty-

eight children attended the program for 30 or more days, for an average of 17.4 (± 1.8) minutes per day. According to pedometer data, over the course of the program children took an average of 987 (± 344) steps and were active at a rate of 58.6 (± 20.8) steps per minute each day at the before school program. Children did not become less active as the program went on, but rather took significantly more steps in mid-intervention and late intervention than in early intervention. Accelerometer data collected during four days of the program showed that participants spent 22.1 (± 8.5) percent of their time at the program in moderate-to-vigorous physical activity. On days that participants attended the program, they spent slightly more time in light, moderate, and vigorous physical activity and took more steps per minute on average during the school day than they did on days after the program was over. Participants also spent less time in sedentary behavior on school days when they attended the before school program versus days without the program, suggesting that students did not compensate on days they were active at the program by being less active during the school day. No differences were seen from early to late intervention in any of the musculoskeletal fitness tests. Analysis of cognitive function measures showed that participants made fewer errors on each of the three CogState assessment tests on days when they engaged in 10 minutes of physical activity at the program compared to days when they did not attend the program before taking the assessments. When participants engaged in physical activity for 10 minutes prior to CogState assessments, they made an average of 7.54 fewer errors during the Groton Maze Learning Task (*ES* = -0.26*)*, 2.25 fewer errors during the One Back Task (*ES* = -0.27), and 33.35 fewer errors during the Continuous Paired Associate Learning Task (*ES* = -*0.*51) than on days when they did not attend the program before taking assessments. When participants took the assessments after 10 minutes of activity, reaction time did not change significantly (mean of the $\log_{10}$ transformed reaction time, 2.96 ± 0.18 vs. 2.95 ± 0.14, *ES* = -

0.04). **Conclusions:** This study suggests that a low-cost, before school physical activity program can positively impact certain domains of cognitive function, including attention, working memory, spatial memory, and executive function. Also, providing children with an opportunity to be active before the school day may help them accumulate more physical activity and spend less time in sedentary behavior during the school day, which may lead to an increase in overall physical activity and associated physical and mental health benefits.

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**Physical Activity, Musculoskeletal Fitness, and Cognitive Function**

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## Dedication

I would like to dedicate this to my late grandfather, Arturo Laureano. My grandfather always emphasized to my sister and I how important education was, how he wanted us to become strong, independent women. He gave so much love and support, and he helped raise me into the person I am today. Thank you for everything you did for me, and for all of your love.

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## Introduction

Physical activity is defined as any bodily movement produced by skeletal muscle that results in an increase in energy expenditure (Caspersen, Powell, & Christenson, 1985). Physical activity is positively correlated with physical fitness, which is the ability to carry out daily tasks with vigor and alertness, and with ample energy. Physical fitness is made up of both health- and athletic-related components.

Physical fitness is composed of, but not limited to, cardiorespiratory endurance, muscular strength, muscular endurance, skeletal muscle power, flexibility, balance, speed, reaction time, and body composition. Exercise is a subcategory of physical activity that is categorized by planned, structured, repetitive movements with the goal of improving or maintaining physical fitness. Regular physical activity and/or exercise are recommended for improvement or maintenance of health, as well as for facilitating growth and development in childhood (Rowland, 2007).

Engaging in regular physical activity and being at or above recommended fitness levels in childhood is important for several reasons. Children who are physically active tend to have a healthier body weight and are more fit than children who are less physically active. Children who are not at a healthy body weight are more likely to be overweight and develop associated problems when they get older. Nieto, Szklo, and Comstock (1992) found that after calculating age- and gender-specific z-scores for height and weight, children in the 5$^{th}$ quintile (80$^{th}$ percentile for the sample) or higher had the highest mortality odds ratios at follow up relative to children in the lower quintiles. In the Fels Longitudinal study, it was observed that exceeding age- and gender-specific weight criteria during childhood, adolescence, and/or the teenage years was a strong and significant predictor (Odds Ratio [OR] = 1.4 - 1.9 for males; OR = 0.8 - 2.8 for females) of metabolic syndrome, a cluster of risk factors that increase the risk of heart disease in adulthood. Excessive weight in youth was also a strong predictor (OR = 1.3 - 16.7 for males; OR = 2.3 – 10.0 for females) of obesity in adulthood (Guo et al., 2000). Regular physical activity may improve body weight and may therefore decrease the risk of developing obesity, metabolic syndrome, and can decrease overall mortality.

Body composition in children may be altered through physical activity. Both adiposity as well as bone mineral deposition and content may be improved with physical activity of appropriate intensities (Heidemann et al., 2013), as is overall lean body mass, including muscle mass in children (Van Der Heijden et al., 2010). Improvements in lean body mass often lead to improvement in overall strength (Annesi, Westcott, Faigenbaum, & Unruh, 2005), which is important considering that many children do not meet recommended levels of muscular strength and endurance, regardless of weight (Aires et al., 2011).

Current physical activity guidelines (United States Department of Health and Human Services [USDHHS], 2008) recommend that children engage in 60 minutes of moderate to vigorous intensity aerobic activity every day. Vigorous activity should be included on at least three days per week. It is also recommended that a child's physical activity regimen include muscle- and bone-strengthening activities on at least 3 days of the week (USDHHS, 2008). Unfortunately, many children do not meet these recommendations, according to both subjective (CDC, 2011) and objective data (Troiano et al., 2008).

Trends in the Youth Risk Behavior Surveillance Survey (YRBSS) suggest an overall increase in sedentary behaviors, such as computer use, in approximately the last 20 years, which may leave less time for physical activity (CDC, 2011). According to the 2011 YRBSS, 14% of children reported not getting 60 minutes of physical activity on any of the seven days prior to the survey. Fifty percent of respondents reported meeting the recommended 60 minutes per day on at least 5 days of the week. Even more concerning is that almost 50% reported not getting any physical education in school within the last week (Eaton et al., 2012). Objective measures of physical activity show that the number of children who meet recommendations is even lower than reported. Troiano et al. (2008) observed, in their accelerometer data, that while on average children engage in an hour per day of moderate-to-vigorous physical activity, less than 42% of all children aged 6-11 years are meeting recommendations. When examining vigorous activity bouts, most children did not accumulate any vigorous activity. By including every minute throughout the day of activity above predetermined cut-points as opposed to accumulated bouts, it was estimated that children 6-11 years obtained between 10 and 16 minutes per day of vigorous activity. For children 12 and older, only 8% met physical activity recommendations of 60 minutes per day of moderate-to-vigorous activity.

With activity levels in children generally lower than recommended, it is imperative to provide additional opportunities for physical activity. Rowland (2007) suggested that intervention before the pubertal years may be needed to develop life-long physical activity and healthy habits. Hearst, Patnode, Sirard, Farbakhsh, and Lytle (2012) reported that, in their longitudinal analysis of adolescent physical activity, baseline physical activity levels were the strongest predictor of activity levels at follow-up. Therefore, they suggested that intervention before middle-school may be needed to encourage physical activity through adolescence. This is particularly important to consider because as children get older, the required school physical education time decreases (National Association for Sport and Physical Education & American Heart Association, 2012) and nearly 80% of children drop out of youth sports programs by the age of 12 years (Beighle & Moore, 2012), making it necessary for children to accumulate physical activity time voluntarily and during leisure time.

Certain variables may affect whether or not a child chooses to voluntarily be active during their leisure time. Variables that have been shown to mediate physical activity participation or the effect of physical activity interventions in children include physical activity self-efficacy and physical activity enjoyment. Self-efficacy is the degree of belief an individual has that he or she can overcome barriers to an activity and is in control of performing the given behavior. Self-efficacy was found to be a strong predictor of physical activity levels up to two years later in boys (Hearst et al., 2012) and was also found to mediate the effects of a school-based intervention in girls (Dishman et al., 2004). Participation in a physical activity program has been shown to increase physical activity self-efficacy (Annesi, 2005; Sung, Yu, So, Lam, & Hau, 2004), which may in turn promote physical activity participation.

In addition to having a positive impact on body composition and fitness, physical activity and fitness levels tend to be positively correlated with various components of psychological well-being (Parfitt & Eston, 2005). In particular, children who participate in regular physical activity and have higher levels of fitness, may also have improved cognitive function compared to children with lower fitness levels. Several studies and meta-analyses have suggested a relationship between fitness and cognition (Buck, Hillman, & Castelli, 2007; Etnier, Nowell, Landers, & Sibley, 2006; Sibley & Etnier, 2003). Cognitive function, often interchangeable with executive function, is a series of top-down mental processes that relate to one's ability to mentally play with ideas, think before acting, conquer new challenges, and maintain focus. Of particular interest with children are cognitive functions of attention and working memory, which may relate to a child's academic performance and their performance in school. This would make the school setting a prime location for incorporating physical activity.

Schools are a convenient location for implementing physical activity interventions, as they are a relatively safe environment with access to a large and diverse group of children. Unfortunately, not all academic advocates are in support of maintaining or increasing physical activity time for children during the school day, and push for a decrease in time for physical activity time in favor of more academic time (Burton & Vanheest, 2007). Physical activity interventions focused on the school environment, but outside of the time designated for the school day may provide a practical alternative.

Programs designed to provide opportunities for physical activity outside of the school day have generally been focused on after school hours and programs before the school day have been limited. One of the only studies to look at a structured before-school physical activity program observed that on days children participated in the before school physical activity program, the children were more attentive and increased on-task behavior by 18%. These children did not compensate for activity accured at the program and decrease their physical activity levels throughout the day (Mahar, Vuchenich, Golden, Dubose, & Raedeke, 2011). A method study (Tompkins, Hopkins, Goddard, & Brock, 2012) that described a planned before-school program has been published, no other published studies were found about before school physical activity programs.

**Purpose Statement**

The purpose of this study was to examine the effects of a before-school physical activity program on different domains of cognitive function; upper body strength, endurance, and power; and physical activity behaviors during the program and during the school day.

**Research Hypotheses**

The following hypotheses were investigated:

1. Participants in the before-school physical activity program will accumulate more physical activity on days that they attend the program than on days they do not attend the before-school activity program.

2. Participants will not compensate throughout the school day by decreasing their activity on days they do attend the program.

3. Participants in the before-school physical activity program will perform better on cognitive assessment tasks after 10 active minutes in the before-school activity program compared to baseline assessment.

4. Upper body strength and power will be increased through activities using the upper body throughout the program.

**Definition of Terms**

***Accelerometer* -** An accelerometer is an activity monitor that detects accelerations in different planes produced by bodily movement.

***Attention* –** Attention is defined as a cognitive selection process of an external or internal event that needs to be maintained at a certain level of focus and awareness.

***Body Mass Index (BMI)*** - BMI is a weight to height ratio. It is calculated by dividing one's weight in kilograms by height in meters squared.

***Cognitive Function* -** Cognitive function is also referred to as executive function, executive control, or cognitive control. Cognitive function refers to a group of top-down mental processes needed when one has to concentrate or pay attention, and when relying on automatic instinct or intuition would be ill-advised, insufficient, or impossible (Diamond, 2012). Different domains of cognitive function are essential for mental and physical health and required under different circumstances.

***Moderate Physical Activity*** **–** Moderate physical activity in this study is defined as physical activity at or above a threshold intensity of 4 METs but below 7 METs. Examples of moderate physical activities include walking, playing catch, and climbing on play equipment.

***Muscular Endurance*** **–** Muscular endurance is the ability of a muscle or group or muscles to exert a submaximal force over an extended period. In the present study, upper body muscular endurance was assessed along with upper body muscular strength using a push-up test.

***Muscular Power*** **–** Muscular power is the ability of a muscle or group of muscles to exert a strong, explosive force as quickly as possible. In the present study, muscular power of the upper body was assessed using a seated, four pound ball toss.

***Muscular Strength*** **–** Muscular strength is the ability of a muscle or group of muscles to exert a maximal force over a short period. Upper body muscular strength was assessed with a handgrip dynamometer. Upper body muscular strength and endurance were assessed with a push-up test.

***Pedometer*** - A pedometer is an activity monitor that measures vertical hip displacement and estimates the number of steps an individual takes.

***Physical Activity*** **-** Physical activity is any bodily movement produced by skeletal muscle that results in an increase in energy expenditure (Caspersen et al., 1985). Physical activity was assessed in the current study with accelerometers and pedometers.

***Vigorous Physical Activity*** **–** Vigorous physical activity in this study is defined as physical activity at or above a threshold of 7 METs. Examples of vigorous physical activity include playing tag, running, and jumping rope.

***Working Memory*** – Working memory is the process of holding information in mind and mentally working with it, such as relating things to each other or by using information to solve a problem (Diamond, 2012).

**Delimitations**

This study included the following delimitations:

1. Participants were third-grade children from a public elementary school in eastern North Carolina.

2. Participants were only able to participate in the study if informed consent was signed by a parent or guardian and obtained by the researchers before the beginning of the study.

3. Cognition was assessed using the CogState Assessment System, and was used to assess the domains of executive function, spatial problem solving, attention, working memory, and visual learning.

4. Physical activity was assessed using accelerometers only during the school day for five days (one week) during and five days after the intervention.

5. Physical activity only during time spent at the program was assessed using pedometers.

**Limitations**

This study had the following limitations:

1. Students arrived at different times to the before-school activity program every day, based on parent drop-off and bus arrival, and sometimes arrived too late to attend the program on a given day.

2. Some students had trouble performing some of the CogState tasks, despite practice and guidance.

3. The program was limited to 25-30 minutes, even during testing days, as researchers were informed students must be let out early enough to get breakfast and so that they would not be late to class.

4. Although all research assistants were trained in test assessments, the same research assistants did not carry out the ball toss and push-up tests each time.

5. Participants may have altered their activity patterns because they were wearing an accelerometer/pedometer.

## Review of Literature

The purpose of this review of literature is to highlight existing evidence in support of and provide rationale for the *First-Class* before-school activity program. This entails discussing the current physical activity and fitness status of United States children and how this matches up to the U.S. Department of Health and Human Services guidelines for both aerobic activity as well as muscle- and bone-strengthening activities. A brief review of the effectiveness of previous interventions, including those that have emphasized muscle- and bone-strengthening activities for children will be included.

This review will then discuss the relationship between physical activity and psychological measures. The relationship between physical activity self-efficacy and physical activity behaviors will be investigated, as well as the relationship between physical activity enjoyment and physical activity behaviors. Also, cognitive function and the different domains of cognition will be discussed as they relate to physical activity and fitness. The relationship between physical activity and fitness and cognitive outcomes may be of particular interest to academic policy makers, as cognitive function may relate to academic performance. If physical activity may improves cognitive function, then the school setting, where children do most of their learning and spend a large portion of their day, may be the optimal location for physical activity interventions.

### Physical Activity and Fitness Levels in Children

Physical activity is defined as any bodily movement produced by skeletal muscles that results in an increase in energy expenditure (Caspersen, Powell, & Christenson, 1985). Physical activity is positively correlated with physical fitness, which is the ability to carry out daily tasks with vigor, alertness, and ample energy. Physical fitness is made up of both health- and athletic ability-related components. Physical fitness is composed of, but not limited to, cardiorespiratory endurance, muscular strength, muscular endurance, skeletal muscle power, flexibility, balance, speed, reaction time, and body composition. Exercise is a subcategory of physical activity that is characterized by planned, structured, repetitive movements with the goal of improving or maintaining physical fitness. Regular physical activity and/or exercise are recommended for improvement or maintenance of health, as well as for facilitation of growth and development in childhood.

Current physical activity guidelines recommend that children engage in 60 minutes of moderate to vigorous intensity aerobic activity every day (USDHHS, 2008). Vigorous activity should be included on at least three days per week. It is also recommended that a child's physical activity regimen include muscle- and bone-strengthening activities on at least 3 days of the week (USDHHS, 2008). Unfortunately, many children do not meet these recommendations, whether physical activity is assessed subjectively or objectively (CDC, 2011; Troiano et al., 2008).

The Youth Risk Behavior Surveillance System (YRBSS) is a self-report assessment that monitors six health risk behaviors of high school youth, including assessment of physical activity and sedentary behavior over the previous 7 days. Trends in the YRBSS show a 10% decrease since 1999 in youth spending over 3 hours in front of the TV per day. Since 2005, however, a 10% increase in computer use over 3 hours per day has been reported, suggesting that children are still spending the same amount of sedentary time in front of a screen each day. According to the 2011 YRBSS, 14% of youth reported not getting 60 minutes of physical activity on any of the 7 days prior to the survey. Fifty percent reported meeting the recommended 60 minutes per day on at least 5 days of the week, but only about 29% reported meeting recommendations of 60 minutes daily. Also, 50% reported not getting any physical education in school within the last week, as high school physical education requirements are minimal (Eaton et al., 2012). These data are from a self-report survey, and subject to overestimation of activity duration or intensity and/or answers influenced by social desirability, which is the tendency to answer in a way that the person believes will be seen as a more favorable answer (Sallis & Saelens, 2000). This opens up the possibility that actual activity levels are even lower than perceived activity levels that are self-reported.

Troiano et al. (2008) used accelerometer data from the 2003-2004 National Health and Nutritional Examination Survey (NHANES) to quantify objectively measured physical activity. The NHANES data were from a cross-sectional study of a nationally representative sample of non-institutionalized civilians in the United States. Objective physical activity monitoring by accelerometry minimizes issues seen with subjective measures of physical activity, such as overestimation and social desirability. Troiano et al. calculated total time spent in moderate-to vigorous physical activity (MVPA) as well as time spent in vigorous activity (VPA). They found that while, on average, children engage in an hour per day of moderate to vigorous physical activity, less than 42% of all children aged 6 to 11 years and 8% of children aged 12-18 years met recommendations. When every individual minute throughout the day of activity above pre-determined cut-points was used rather than consecutive minutes of activity, children 6 to 11 years of age obtained between 10 and 16 minutes per day of vigorous activity. When only examining bouts of activity where children had consecutive minutes of vigorous activity (i.e., 5 minutes in a row), the amount of vigorous activity dropped to almost zero. This suggests that children's activity is sporadic, and not typically acquired in bouts, as is seen with adults. Despite opportunities that may be presented in school and outside of school for children to be physically active, it is clear from objectively measured data that a large majority of children do not engage in enough MVPA to meet physical activity recommendations.

Increasing physical activity levels in children is important for several reasons, as regular physical activity during childhood has been suggested to be critical during development. Benefits of physical activity include reducing risk of many chronic diseases and premature death, improving physical fitness and functional capacity, and improving mental health and cognitive function. Initiating regular exercise behaviors at an early age is expected to be an effective strategy for decreasing risk of developing poor metabolic health and associated diseases in adulthood (Rowland, 2007). Therefore, it may be important to investigate predictors of physical activity behaviors in children in order to determine when and how to best intervene and improve physical activity levels.

In a two-year longitudinal study conducted with 578 adolescents ages 10 to 16 years, Hearst, Patnode, Sirard, Farbakhsh, and Lytle (2012) measured physical activity using Actigraph accelerometers. Multilevel psychological, behavioral, and social determinants of physical activity were assessed with questionnaires administered to the parents. A home physical activity equipment inventory was also administered. The authors predicted that the intrapersonal factors, environmental factors, and behavioral experiences regarding physical activity that children and their parents report would predict physical activity behaviors by children. After two years, the authors found that the strongest predictor of physical activity at follow-up was physical activity level at baseline. The authors suggested that these findings may support the idea that physical activity intervention before the middle school years may be needed to influence habits later.

Regular physical activity may also result in improved body composition, one of the components of physical fitness. Body composition is often of particular concern when considering physical activity levels of a childhood population which is growing increasingly more overweight. In 2010, a record high of more than one-third of children and adolescents were overweight or obese. Overall, the mean BMI for children between the ages of 6-11 years increased 0.4 $kg/m^2$ (17.9 to 18.3 $kg/m^2$) for males and 0.5 $kg/m^2$ (18.0- 18.5 $kg/m^2$) for females from the 1999-2000 school year to the 2009-2010 school year. Increases in mean BMI were also observed in children between the ages of 12-19 years, with the mean BMI for males increasing 0.9 $kg/m^2$ (22.9 to 23.8 $kg/m^2$) and the mean BMI for females increasing by 0.3 $kg/m^2$ (23.3 to 23.6 $kg/m^2$) (Ogden, Carroll, Kit, & Flegal, 2012).

Other NHANES data from 4,111 children and adolescents with available measures of height and weight shows increasing overweight prevalence across age groups, as the number of overweight children in each age group increases through childhood and adolescence (Ogden, Carroll, Curtin, & Lamb, 2010). Up until age 2 years, babies and toddlers were identified as overweight or obese if they were at or above the $95^{th}$ percentile on weight-for-recumbent length growth charts. From age 2-19 years, children were identified as overweight if their BMI was at or above the $95^{th}$ percentile for age- and gender-specific BMI growth charts. The children from the NHANES sample ranged from birth to 19 years of age, with more children in the older groups being identified as overweight and obese. This makes sense, as childhood overweight and obesity is a result of a long-term positive energy balance (Butte, Christiansen, & Sorenson, 2007). This imbalance occurs when calories consumed exceeds calories expended by metabolism and through physical activity. Children who are older and have been in a positive energy balance long-term are likely to accumulate more weight, leading to a larger percentage of children in older age groups being overweight or obese. Intervention early on may be necessary to promote negative or an even energy balance and increase the chance of having lasting impacts into adulthood.

Rowland (2007), in an article providing rationale and strategies for promoting physical activity for children's health, suggested that intervention before the pubertal years may be needed to develop life-long physical activity and healthy habits. Developing these habits may increase the chances that children keep up being active on their own, which is important since as children get older the required physical education time decreases (NASPE & AHA, 2012) and nearly 80% of children drop out of their youth sports programs by the age of 12 years (Beighle & Moore, 2012). This means that many older children are left with only leisure time to accumulate physical activity voluntarily.

Children who do not accumulate enough activity in their leisure time may become overweight, which can have lasting consequences. Nieto, Szklo, and Comstock (1992) measured the effect of growth and relative weight in childhood on adult mortality in a sample of 13,146 people whose weight and height were measured each year between the ages of 5 and 18 years. Relative weight was calculated using age- and gender-specific height z-scores for weight. Their data showed that children in the $5^{th}$ quintile ($80^{th}$ percentile for the sample or higher) for relative weight had the highest mortality odds ratios relative to children in the lower quintiles. The mortality odds ratio was largest for females who were in the $5^{th}$ quintile after puberty, with their mortality odds ratio being about two times that of the girls in the lowest quintile measured after puberty.

Another longitudinal study, the Fels Longitudinal Study, was created to study child growth and development. Results of this study demonstrated that weight and waist circumference in childhood were related to both obesity and metabolic syndrome in adulthood. BMI patterns during early childhood, pubescence, and post-pubescence of 180 males and 158 females were examined. Exceeding age- and gender-specific weight criteria during early childhood (5-7 years), pubescence (8-13 years), and/or post-pubescence (14-18 years) was a predictor (*OR* = 1.4-1.9 for males; *OR* = 0.8-2.8 for females) of metabolic syndrome in adulthood. Excessive weight in youth, particularly between ages 14 and 18 years was a strong predictor (*OR* = 1.3-16.7 for males; *OR* = 2.3-10.0 for females) of obesity in adulthood several years later (Guo et al., 2000). Odds ratios were highest for both genders (*OR* = 16.7 for males, 10.0 for females) if children exceeded weight recommendations in post-pubescence, suggesting that once children get older, they are likely to remain overweight and/or develop metabolic syndrome if they are overweight, and earlier intervention may be desirable.

In addition to negative health consequences in adulthood, overweight children may also see consequences related to their weight status during childhood. Ruiz et al. (2006) objectively measured total physical activity of 780 Swedish and Estonian 9- and 10-year-old children with accelerometers using 1-minute epochs and compared activity levels of various intensities to fitness and fatness. Using multiple regression analysis, the authors reported that moderate, moderate-vigorous, and vigorous physical activity all significantly explained cardiovascular fitness. Lower body fat, however, was only associated with vigorous physical activity and cardiovascular fitness level. Ruiz et al. suggested that total time spent in physical activity was not as important as the intensity of the activity when obesity prevention is the goal, but physical activity of both moderate and vigorous intensities may improve cardiovascular fitness. While this study highlights the importance of vigorous intensity physical activity when targeting body composition, it also suggests that both moderate and vigorous intensity physical activity is important for all children to improve cardiovascular fitness.

Aires et al. (2010) found that when six tests from the *FITNESSGRAM* were administered in a group of 636 adolescents aged 11-18 years, BMI category was strongly and inversely related with percent of participants falling within the Healthy Fitness Zone. The relationship was stronger among girls than among boys. In this sample, 100% of participants classified as obese of both genders did not achieve the Healthy Fitness Zone for the shuttle run. After calculating odds ratios, failing to achieve the Healthy Fitness Zone for push-ups was shown to be the strongest predictor of both overweight ($OR = 2.454$) and obesity ($OR = 5.641$) in girls and overweight in boys ($OR = 1.888$) of all of the physical fitness tests. Failing to achieve the Healthy Fitness Zone for curl-ups was the strongest predictor of the physical fitness tests examined of obesity in boys ($OR = 7.138$). All obese children were categorized as “unfit”, which meant failing two or more tests. Physical fitness is related to overall health, and overweight and obese children are already at an increased risk for various hypokinetic diseases. Therefore, improvement of fitness levels, in addition to increasing physical activity levels, should be a priority for youth, particularly for those who are overweight or obese.

**Importance of Muscle and Bone Strengthening Activities for Children**

When addressing physical activity concerns and creating interventions for children, the type of activity discussed is most often aerobic in nature. As recommended by the U.S. Department of Health and Human Services (2008), however, muscle and bone strengthening exercises are also important. While not traditionally used with younger populations, resistance training has been found to be safe for children. Reviews have suggested that an appropriate, supervised resistance training program is safe and effective in developing muscular strength and endurance in youth (Faigenbaum et al., 2009), with injury rates similar to that of many sports, and lower than those found in football and gymnastics (Faigenbaum & Myer, 2009).

A variety of resistance training protocols designed for children composed of varying intensities, frequencies, and durations have been successful in eliciting improved muscular strength and endurance (Faigenbaum et al., 2009). Wide ranges of improved strength have been seen with resistance training protocols of different intensities and varying program lengths.

Yu, Sung, Hau, Lam, Nelson, and So (2008) reported significant and desirable changes in strength and body composition outcome measures after a six week intervention. In their study, 82 overweight and obese children ages 8-11 years were randomized into a diet only or diet and exercise group. Participants in the diet and exercise group exercised three times per week for six weeks, where each exercise session lasted about one hour and consisted mostly of muscle- and bone-strengthening exercises. This hour included a warm-up and cool down, 30 minutes of resistance training, 10 minutes of aerobic exercise, and 10 minutes of agility training. Handgrip strength, shuttle-run, sit-up, and push-up scores all improved significantly after just six weeks in both the diet-only and combination group, but to a significantly greater extent in the diet and exercise combination group. In addition to strength measures, both groups perceived themselves to be stronger after the intervention. BMI decreased significantly in both groups, and lean body mass increased in both groups, but significantly more (more than double) in the diet and exercise combination group. This study showed that as little as six weeks of an exercise intervention with a focus on resistance training exercises can elicit positive changes in muscular strength, endurance, and body composition outcomes.

Aires et al. (2010) examined the association between the components of physical fitness measured by the *FITNESSGRAM* and BMI levels, and found that an increase in BMI category was associated with a decreased percentage of youth passing each test. However, data revealed that many students categorized as normal weight were also identified as unfit, failing two or more tests. Over half of males and over two-thirds of girls in both the normal and overweight categories were identified as unfit, and 100% of both boys and girls in the obese category were classified as unfit. When examining performance in the individual fitness categories, about half of all girls and boys in both the normal and overweight groups were not in the Healthy Fitness Zone for upper body strength, and over 75% of boys and over 90% of girls in the obese group were below Healthy Fitness Zone requirements for upper body strength. This suggests that upper body strength in particular may be below what is recommended for health in most children, and should be targeted for improvement.

While consistent findings suggest that resistance training can elicit desirable changes in body composition, such as increases in lean body mass in children (Anessi, Wescott, Faigenbaum, & Unruh, 2005; Faigenbaum et al., 2009; Van Der Heijden et al., 2010; Yu et al., 2008). Many of these studies look at changes in muscle mass as the primary improvement in lean body mass. Changes in other components of lean body mass, such as bone health and growth, have also been observed in children after a strength training program.

Physical activity, depending on the intensity, can impact bone mineral accumulation in childhood, which can decrease the risk for bone mineral deficiencies later in life. Heidemann et al. (2013) published results from the CHAMPS study, which implemented additional physical education lessons for children from pre-school to 4$^{th}$ grade in intervention schools, while keeping physical education in other schools as usual and sought to determine if intensity of physical activity had an impact on bone mineral content, bone mineral density, and bone area. The researchers measured physical activity with accelerometers and used dual energy x-ray absorptiometry to measure bone mass. Complete data were collected on 602 children, aged 11.5 (*SD* = 0.88) years. At program follow-up two years later, the researchers found a statistically significant, positive relationship between the log odds of minutes of moderate-to-high level physical activity versus sedentary and low level activity and the measured bone characteristics at follow-up. A positive relationship was reported between bone mineral density and the log of the proportion of time spent in moderate-to-high level physical activity, as well as bone area accretion and the log of the proportion of time spent in moderate-to-high level physical activity. No relationship was found between bone mineral density or bone area accretion and time spent in sedentary and light levels of activity. This study suggests that childhood, when bones have not yet fully developed, may be an optimal time to shift the distribution of time spent in sedentary and light level activities to activities of moderate and hard intensity. Encouraging children to limit time spent in sedentary and low-level activities so as to engage in physical activity above a certain threshold intensity may increase bone mass by positively influencing bone mineral density and increasing bone area, and can potentially limit fragility in later life.

Another study that measured bone health focused on obese children. Van Der Heijden et al. (2010) had 12 obese adolescents aged 15.5 (*SD* = 0.5) years complete a 12-week, bi-weekly resistance training program. Weight post-intervention increased, attributable to increased lean body mass without a change in fat mass. The researchers also reported that the training intervention elicited a small but significant increase in bone mineral density (0.015 g/cm$^2$). This suggests that bone mineral density improves in all kids, and the benefits can be generalized to include obese children.

Participation in any program, including one incorporating strength activities, may have alternative benefits that extend beyond changes in body composition. In a randomized controlled trial of already physically active young ice-hockey players (Eiholzer et al., 2010), 25 participants aged 13.1 years (*SD* = 1.0) engaged in a bi-weekly, high-intensity resistance training program for 12 weeks. Participants were randomized into either a control group which continued their regular physical activity or practice programs, or into the bi-weekly intervention consisting of structured resistance training. The intervention program increased spontaneous physical activity energy expenditure outside of the program measured by an accelerometer. Changes in spontaneous energy expenditure were moderately correlated with in-training energy expenditure levels ($r$ = .67) in the intervention group, but not with changes in arm, leg, or trunk strength, or with changes in lean body mass and fat mass. Spontaneous physical activity energy expenditure increased in the intervention group by 25.5% at the end of the 4 month intervention, and remained 13.5% higher than baseline after a 12 month washout period. The intervention group also had significantly higher arm and leg strength levels than the control group through the washout period. No significant differences in lean body mass or fat mass existed between the groups at any point. If spontaneous physical activity can be increased in children who are already physically active, those with lower baseline values of physical activity may have more room for improvement than children who are already active.

A physical activity protocol described by Annesi, Westcott, Faigenbaum, and Unruh (2005) was delivered by YMCA after-school counselors previously untrained in physical education methods for 45 minutes, three times per week, for 12 weeks. The program was administered to 226 girls and 344 boys, predominantly of a minority status, aged 5-12 years. The researchers incorporated resistance training on two out of their three days per week as recommended by the U.S. Department of Health and Human Services. Body composition was estimated from the triceps and calf skinfolds, muscular strength was assessed using a push-up test to a 3-second cadence, flexibility was measured using the shoulder stretch test, and endurance was measured using a one mile run/walk. To account for physiological differences, children were split into one of four age groups: 5-6 years, 7-8 years, 9-10 years, and 11-12 years. Groups were analyzed separately by gender. Body composition was improved in all groups (*Cohen's d* = 0.21-1.02 for girls, *d* = 0.67-1.64 for boys) except 5-6 year old boys, where the decrease in percent fat was not significant. Strength significantly increased by a relatively large amount in all groups (*Cohen's d* = 1.33-2.32 for girls, *d* = 0.75-1.95 for boys). Flexibility slightly improved in all age groups for boys and in the 9-10 year age group for girls. Endurance measured from the mile run/walk was only tested in the 9-10 and 11-12 year age groups. All groups showed a significant improvement in mile run/walk time. The added resistance component is believed to be the reason for the uniform increase in strength among all groups beyond what could have been expected from maturation alone. The authors controlled for predicted changes in maturation, which supports the idea that the resistance training was responsible for the relatively large increases in strength.

Available research suggests that muscle- and bone-strengthening activities are safe and effective for children of all ages and across different abilities. Therefore, any physical activity program for children should place some emphasis on such activities, with the goal of two or three days per week in accordance with U.S. Department of Health and Human Services guidelines.

**Physical Activity and Psychological Outcomes**

The existence of a mind-body relationship where mental health is related to physical health and fitness has been suggested in several domains of science. Physical activity and exercise have been shown to positively impact self-esteem, depression, self-efficacy, and multiple domains of cognitive function. In a systematic review, Ekeland, Heian, and Hagen (2005) concluded that based on pooled data from available low quality research trials with participants aged 3-20 years, exercise may improve self esteem. In their review, interventions consisting of exercise alone and interventions consisting of exercise combined with other counseling were both about equally successful in improving self-esteem. In interventions consisting of exercise alone, 13 studies yielded a standardized mean difference of 0.49, in favor of the exercise intervention. In interventions using exercise as a component of a comprehensive intervention, 12 studies yielded a standardized mean difference of 0.51. For both exercise alone and comprehensive interventions the standardized mean difference corresponded to approximately a 10% difference in self-esteem scores on questionnaires between the intervention and control groups. The authors classified this change as a moderate effect. This review suggested that participation in or starting an exercise program alone may be enough to improve self-esteem.

Aside from looking at exercise participation, Parfitt and Eston (2005) investigated the relationship between physical activity levels as measured by pedometer steps recorded over 7 days and various components of psychological well-being as measured by the State-Trait Anxiety Inventory for Children, Childhood Depression Inventory, and the Child and Youth Physical Self-perception Profile. The sample of 35 boys and 35 girls was composed mostly of normal weight children aged 9.8-11.4 years. Analysis of the data showed that physical activity level measured by number of steps was significantly and negatively related to anxiety ($r$ = -.48) and depression ($r$ = -.60) and positively related to global self-esteem ($r$ = 0.66). The authors concluded that children who accumulated over an average of 12,000 steps per day had more positive psychological profiles than children who took fewer than 9,200 steps per day on average.

In addition to aerobic exercise as investigated in the aforementioned studies and physical activity measured by pedometers, resistance training may help improve psychological well-being in youth (Faigenbaum et al., 2009). Many physical activity interventions in childhood do not include time for resistance training, despite recommendations by the USDHHS to include muscle- and bone-strengthening exercises on at least three days per week. Faigenbaum et al. (2009) also reported that clinicians found that children who resistance trained exhibited similar socialization (i.e., camaraderie) and mental discipline to those who were team sport participants, and that resistance training programs improved attitudes toward physical education, fitness, and exercise. This suggests that resistance training may have multiple psychological benefits, and can be suitable for children of many different ability levels.

Self-efficacy refers to the confidence one has that he or she is in control of engaging in a certain activity or reaching a goal. Self-efficacy has been identified as a correlate of physical activity, and may mediate the effect of a physical activity intervention in children. Dishman et al. (2004) evaluated the effects of a school-based program entitled the Lifestyle Education for Activity Program (LEAP) on cognitive constructs from the social cognitive theory in adolescent girls. The outcome variables that were found to have a significant relationship with physical activity levels self-reported using the 3-Day Physical Activity Recall were self-efficacy, outcome-expectancy value measured from eight items on a questionnaire, and satisfaction measured by one item. The LEAP program produced statistically significant but small effects on self-efficacy, goal-setting, and physical activity. Almost all of the cognitive constructs were found to have significant and direct effects on physical activity levels, thus allowing the authors to conclude that the effect of the intervention on physical activity levels was partially mediated by those cognitive constructs, including self-efficacy. This suggests that interventions aimed at increasing physical activity levels should target cognitive constructs, particularly self-efficacy, to maximize the potential impact of the intervention.

Interventions that consider important psychological outcomes may help all children benefit from physical activity interventions and limit the effectiveness targeting only select groups. In a cross-sectional study, Sung, Yu, So, Lam, and Hau (2004) compared scores of normal weight and overweight children ages 8-12 years on Marsh's Physical Self-Descriptive Questionnaire. This questionnaire measures nine specific components of physical self-concept, including health, coordination, physical activity, body fat, sports competence, appearance, strength, flexibility, and endurance, as well as provides a measure of global physical self-concept and global self-esteem. Overweight children perceived themselves to have significantly more body fat, and poorer appearance, sports competence, endurance coordination, flexibility, and overall physical self-concept and self-esteem than normal weight children. However, overweight children did not perceive themselves to be any less healthy, physically active, or strong, and actually perceived themselves to be significantly stronger than their normal weight peers. Athletic incompetence is likely highlighted during competitive team games where speed and coordination may be most important. Non-competitive games or activities focusing on resistance exercises have the potential to improve physical self-concept in all children equally.

In a 6-week intervention program that randomized participants into a diet-only and a combination diet and resistance training group, Yu et al. (2008) measured physical self-concept of the participants using Marsh's Physical Self-Descriptive Questionnaire to see if physical activity could change response scores. The combination group, in addition to the prescribed diet, performed 30 minutes of strength training along with 10 minutes of aerobic exercise and 10 minutes of agility exercises three times per week. Both groups experienced similar decreases in

BMI and percent body fat, though the combination group had a statistically significantly larger increase in lean body mass (0.8 kg) than the diet-only group (0.3 kg). After analyzing the psychological variables, it was found that both groups significantly increased confidence in their strength. Those in the diet and resistance training combination group also increased their endurance self-concept by an average of 0.3 points on a 6-point scale.

Annesi (2005) compared data from an after-school program carried out in 2003 to a modified program carried out in 2005. The 2005 program consisted of a modified behavioral skills component and the addition of a nutrition component to determine if there were differences in self-efficacy changes, and if voluntary physical activity changed. The modified program had slightly better outcomes than the 2003 program, but both were comparable. It was concluded that a 12-week after-school program of 45 minutes, 3 days per week consisting of non-competitive games and tasks on each day and 2 days per week of resistance training had positive benefits on psychological outcomes in both 2003 and 2005. The children in the program increased frequency of voluntary physical activity and improved in both physical self-concept and exercise barriers self-efficacy. Physical self-concept was measured using the Physical Self-Concept Scale: Child Form intended for children aged 7-14 years and included item clusters of identity, satisfaction, and behavior. Exercise self-efficacy was measured using the Exercise Barriers Self-Efficacy Scale for Children, which measures the children's perception of whether or not they have the ability to overcome social, personal, and environmental barriers to participating in exercise. If self-efficacy for physical activity can be increased, children may be more likely to engage in physical activity on their own. This suggests that increasing physical activity self-efficacy should be considered during the implementation of any physical activity intervention.

***Physical Activity Enjoyment.*** Physical activity participation has been found to be strongly and positively correlated with physical activity enjoyment. This is to be expected, as people do not usually voluntarily engage in activities they are do not receive pleasure from doing. Enjoyment of physical activity is an intrinsic motivator, which is the highest quality of motivation one can have according to Deci and Ryan's (2000) self-determination theory. Based on the level and degree of an individual's motives to engage in a behavior, a person has a certain level of motivation. Motivation is not dichotomous, and is more than just present or absent. Deci and Ryan propose that motivation lies on a continuum from amotivation, or the absence of motivation, to the highest level of motivation, intrinsic motivation. Motivation is categorized as either intrinsic or extrinsic, depending on what regulates the person's motivation. Intrinsic regulation is the highest level of motivation, and the only level of motivation on the continuum classified as intrinsic motivation. Individuals driven by intrinsic motivation engage in a behavior because they personally enjoy the behavior. Extrinsic motivation, from lowest level to highest level of motivation includes external regulation, introjected regulation, identified regulation, and integrated regulation. External regulation is the least autonomous level of motivation, and is when a person is only motivated by an external demand (e.g., reward or punishment). A person's motivation is characterized as introjected regulation when he or she engages in the behavior because of fear or because of either guilt or ego reasons (e.g., self-approval). Identified regulation leads people to engage in a behavior because they see how the behavior may be beneficial. The highest level of extrinsic motivation is characterized as integrated regulation, where people fully accept the behavior within themselves and feel the behavior is right or suitable personally. Amotivation is the absence of motivation and therefore is not classified as being driven by intrinsic or extrinsic regulation, but rather is considered non-regulated. As one moves up the continuum of self-determination, the quality of motivation increases and a person is more likely to engage in the specific behavior. The different types of regulation represent the quality of the motivation, which is believed to be more important than simply the amount of motivation. Since intrinsic motivation is only achieved through personal enjoyment from, or interest in, a behavior and a person is more likely to participate in a behavior if he or she is intrinsically motivated, physical activity enjoyment is likely to be a strong mediator of physical activity participation. Enjoyment should be considered in any physical activity intervention.

Physical activity enjoyment may help predict physical activity levels among both boys and girls. DiLorenzo, Stucky-Ropp, Vander Wal, and Gotham (1998) conducted a three-year longitudinal analysis of 111 children, in fifth- and sixth-grade at baseline, to investigate determinants of exercise levels in children. The researchers measured physical activity levels using a physical activity interview, which was used to estimate the time spent in various activities throughout the child's day and the intensity of those activities. Operant and social learning variables believed to be related to exercise participation were measured by the Children's Physical Activity Questionnaire, modified from a previous version by the authors. Variables measured by this questionnaire include the child's self-efficacy for physical activity, child-reported parental modeling of physical activity, enjoyment of physical activity, and exercise knowledge. Physical activity levels and perceptions of the parents were measured using the Parental Physical Activity Questionnaire, which asked about exercise habits, social learning variables, and the parents' opinions about their child's exercise habits. The variables measured in this questionnaire included negative indicators of the child's physical activity (i.e., television watching), parental self-efficacy for physical activity, and parental enjoyment of physical activity.

Regression analyses were carried out to determine factors that were predictors of the child's physical activity levels. For girls, child's enjoyment of physical activity was the only variable that entered the stepwise regression equation, accounting for 3% of the variance. For boys, child's enjoyment was also a significant predictor of physical activity, and accounted for 16% of the variance in physical activity levels. For boys, the child's perceived friend and family modeling/support as well as the parent's perceived negative family support also were significant predictors of the child's physical activity. For boys, these three factors accounted for 25% of the variance in physical activity levels. The child's reported physical activity enjoyment was the only consistent predictor of physical activity level among all children (boys and girls) and was the only significant predictor for girls. The authors suggested that this was important because other variables that predicted physical activity levels at follow-up regarded parental support and parental behaviors, something that may not be as controllable as enjoyment. Also, the small variance accounted for by enjoyment may be because in young age groups, most children enjoy physical activity. Also, the study did not focus on leisure time activity, but rather weekdays where children in school all have similar schedules, which would likely lead to similar amounts of time spent in different activities when measured using a physical activity interview. If children enjoy an activity, they are more likely to engage in that activity. Enjoyment should be a main goal in any physical activity intervention in children.

Measurement of psychological constructs in childhood is often difficult, as reading and comprehension abilities vary greatly among youth. Kendzierski and DeCarlo (1991) provided evidence of validity for the Physical Activity Enjoyment Scale (PACES), a single-factor, multiple-item scale to assess physical activity in adults. They validated their scale in two different studies where the subjects exercised in a closed environment, either on a bike or treadmill, with or without external distraction, and with or without choice of which activity to perform. The PACES was found to have high internal consistency and the authors recommended their scale for further use. Since then, the scale has been modified to be more appropriate for children. Moore et al. (2009) reported evidence of validity for a modified version of the original PACES. The researchers pilot tested the PACES in an independent sample of 564 third graders, and with assistance from a third grade, remedial reading master teacher, used their pilot data to determine if the questionnaire was appropriate for that age group. Minimal changes to the original PACES included the removal of two items and re-writing of others in order to improve comprehension and reduce redundancy. Scores on the modified PACES were significantly correlated with task goal orientation ($r$ = .65), athletic competence ($r$ = .23), physical appearance ($r$ = .20), and self-reported physical activity ($r$ = .16), suggesting good convergent validity. The results provided evidence of validity for their modified scale in a third grade population, showing good internal consistency and item-total correlations.

***Cognition.*** It has been suggested in different studies and in meta-analytic reviews that a positive association exists between physical activity participation and cognitive function. With the human brain being so complex and able to work in so many different ways, cognitive function is split into different dimensions. The dimension most often focused on in current research on physical activity and fitness is executive function. Diamond (2013) describes executive functions as those that allow for mentally playing with ideas, thinking before acting, conquering new challenges, resisting temptations, and maintaining focus. The core executive functions include inhibition and inference control, working memory, and cognitive flexibility.

Diamond (2003) stated that inhibitory control involves being able to control attention, behavior, thoughts and emotions, to ignore an internal predisposition or external distraction, and therefore perform what the appropriate task requires. It involves the control of impulses and habits. Working memory involves keeping information in mind and working with it after the information is no longer present. Working memory is needed to understand anything that unfolds over time and/or when relating a sequence of stimuli. Working memory differs from short-term memory, which is simply holding the information in mind and being able to recall the information. Cognitive flexibility is being able to spatially change perspectives by inhibiting a previous perspective and taking on another, essentially changing how one thinks about something. It involves being able to adjust thoughts and actions based on arising demands or priorities, acceptance of error or being wrong, and taking advantage of sudden opportunities. While Diamond (2013) described cognitive flexibility as building off the other two core executive functions and as developing later in life, it is not considered a higher-order of executive function. Fluid intelligence is the ability to abstractly reason and problem solve and connect items with patterns or relations using inductive and deductive logical reasoning and requires higher levels of executive function and control.

Many studies of cognitive function have focused on adults and older adults, when cognitive decline becomes a pressing issue. According to Etnier, Nowell, Landers, and Sibley (2006), prior research and meta-analyses gave way to the assumption that changes in aerobic fitness resulting from physical activity contribute to the changes in cognitive performance. These researchers then conducted a meta-analysis to examine the relationship between physical fitness improvements from physical activity and cognitive performance, and test the cardiovascular fitness hypothesis. The cardiovascular fitness hypothesis states that changes in cardiovascular fitness must be observed in order for cognitive benefits from physical activity to be achieved.

The meta-regression analysis included 571 effect sizes (*ES*) and data from approximately 1,306 healthy subjects in 37 different studies from 1966-2004. When they used an average *ES* from all 37 studies, the mean *ES* for the effect of physical activity on cognition was 0.34 ($SD$ = 0.30), which supports the conclusion that physical activity is associated with a small improvement in cognition and that cognition and physical activity are positively correlated. The mean *ES* for physical activity on cardiovascular fitness was 1.13 ($SD$ = 1.51), which supported the conclusion that physical activity is positively correlated with fitness. The authors did not observe any significant relationships between fitness and cognition when examining only those studies with cross-sectional designs, where participants were examined only at one time point. The authors explained the lack of a significant relationship, stating that the advantage trained individuals had over untrained individuals in cognition was not predicted by the difference in fitness levels between the two groups. For pretest-posttest comparisons, the mean effect size for physical activity on cognition was 0.25, and the mean effect size for physical activity on cardiovascular fitness was 0.55. However, linear regression analyses indicated a significant negative relationship was found between aerobic fitness and cognitive performance for pretest-posttest comparisons, and larger improvements in aerobic fitness were predictive of lesser improvements in cognitive performance. In studies where participants had large increases in fitness, smaller improvements in cognitive function were found. Studies with interventions yielding smaller increases in fitness were indicative of larger increases in cognitive function. This led the authors to conclude that existing studies using cross-sectional designs and pretest-posttest designs do not support the cardiovascular fitness hypothesis. Of their 10 studies that reported the strength of the relationship between fitness and cognition, 29 Pearson correlations were provided ranging from .04 to .68, with a mean of $r = .29$. The most common tests of cognition from these studies were tests of memory and choice reaction time. The authors concluded that their overall *ES* was not significantly different from those found in previous studies and analyses, and that physical fitness is associated with a small effect on cognition. However, based on the negative relationship between fitness and cognition observed when looking at the cross-sectional studies alone, they stated that the available literature did not support that cardiovascular fitness was related to cognition, and that other variables (such as physical activity) that potentially mediate cognitive abilities should be researched. This could be due to the fact that participants in the studies included in the analysis were mostly adults, whose brains are already fully developed and potentially resistant to change. It is possible for the effects to be present and manipulated in children, particularly early on in life, and the authors discussed that the conclusions from their review may not be generalizable to younger populations. Although physical activity can have benefits for individuals of all ages, early intervention may be required to improve or maintain cognitive health and function throughout the rest of one's life, as children's brains are still developing and may be more alterable than fully developed adult brains (Hillman, Erickson, & Kramer, 2008).

In a meta-analysis, Sibley and Etnier (2003) sought to examine the relationship between physical activity and cognition focusing on children, as it was believed that the relationship may be different in children whose brains are constantly changing and absorbing knowledge in a different way than adults. The authors found in their literature search only nine peer-reviewed studies using a true experimental design that met their inclusion criteria; however, they also found seven unpublished studies that used a true experimental design, and those were also included in the analysis. The authors ended up with 107 effect sizes, and reported a significant overall effect size of 0.32 (*SD* = 0.27), which was larger than the effect size of 0.25 found in a separate, previous meta-analysis the authors had carried out which included all age groups. No significant differences were found between different levels of experimental design, and all had *ES* significantly larger than zero. Unpublished studies had a significantly larger *ES* than published studies, but both were significantly larger than zero, and the authors concluded that there was likely no publication bias in publishing studies only with positive outcomes, as unpublished studies had a higher overall *ES*. This meta-analysis suggests that physical activity may have a particularly beneficial effect on cognition in children, given that their overall *ES* was larger than those seen in previous analyses that included all age-groups.

Sibley and Etnier's (2003) meta-analysis also examined moderator variables, to determine the generalizability of their conclusion. Experimental design, participant health status, and activity type were all found to be insignificant moderators of intervention outcomes, suggesting that physical activity has a positive relationship with cognition in all design types and for all levels of participants. Age group, publication status of the study, and cognitive assessment used were all found to be significant moderators of the physical activity and cognition relationship. Students were analyzed in different age groups, and were classified as early elementary (4-7 years), late elementary (8-10 years), middle school (11-13 years), and high school (14-18 years). Middle school and elementary school children received the most benefit from physical activity, which was expected as the authors stated previous research had suggested that physical activity may be particularly important to the cognitive development of young children.

Finally, Sibley and Etnier (2003) observed that the type of cognitive assessment was found to be a significant moderator of the relationship between fitness or activity level and cognition or academic performance variables. Physical activity had the largest effects on perceptual skills and academic readiness, with effect sizes of 0.49 (*SD* = 0.12) and 0.39 (*SD* = 0.44), respectively. An "other" category which included areas such as creativity and concentration, yielded an effect size with physical activity of 0.40 (*SD* = 0.21). Memory was not related to physical activity, with a small effect size of 0.03 (*SD* = 0.19). Studies using math and verbal tests as measures of cognition showed that physical activity yielded effect sizes of 0.20 (*SD* = 0.31) and 0.17 (*SD* = 0.47) on math and verbal scores, respectively. Of particular interest from this analysis are the sizes of the effects of physical activity on IQ and academic achievement (*ES* for IQ = 0.34; *ES* for academic achievement = 0.30). Sibley and Etnier suggested that IQ and academic achievement are likely the two areas of cognition of most importance to educators, and according to the authors are the domains of cognition under consideration when physical activity time is cut in school in favor of more academic time. This meta-analysis provides evidence to suggest that the approach of cutting physical activity time may actually have the opposite of the desired effect on IQ and academic achievement. The authors concluded that their study provided support for the idea that physical activity can be included at school without compromising academic achievement, and at the very least it can be said that physical activity will not hurt cognitive or academic performance in children. Analysis of the moderator variables also suggests which areas of cognitive function may be most influenced by physical activity and which domains show the most promise for future research.

Chaddock et al. (2010), through their use of neuroimaging to determine the association between brain hippocampal volume, fitness, and memory, claim to be the first to find that aerobic fitness may relate to the structure and function of the preadolescent human brain. Their study participants consisted of children aged 10 years (*SD* = 0.6) split into two categories: 28 low-fit children with an average $VO_2$ max of 36.4 ml/kg/min (*SD* = 4.0) and 21 high-fit children with an average $VO_2$ max of 51.5 ml/kg/min (*SD* = 4.3). Children who were more fit had a larger hippocampal volume and better performance on a memory task than less fit children. While genetics may account for some of the variability in aerobic fitness, physical activity levels may also predict aerobic fitness levels. The authors suggested that physical activity may indirectly affect brain development and function through improvements in physical fitness.

Brain physiology and hippocampal volume may not be the only factors related to cognitive function affected by adaptations to physical activity and/or fitness. According to a review by Haapala (2013), available research suggests that physical activity or exercise training may improve cognitive performance by improving cardiorespiratory fitness and/or motor skills in childhood. The author stated that highly fit children have larger subcortical brain structures, more efficient brain activation, better inhibitory control, and better working memory and attention related to cognitive tasks then less fit children. Also, children with better motor skills have better inhibitory control and attention capacity than children with poorer motor skills. Haapala suggested that children who are stimulated through physical activities in their environment may improve the functions of their cardiovascular and neuromuscular system, thus affecting brain health and function.

Buck et al. (2007) measured aerobic fitness levels using the *FITNESSGRAM*, and compared fitness with performance on the Stroop color-word task in 74 children 7 to 12 years old. The Stroop color-word task involves matching colors and words, which measures cognitive processes of executive control including selective attention, response inhibition, interference control, and speeded responding. During this task, three conditions requiring increasing interference control are presented. In the first task, participants are shown color words spelled out in black ink, and are instructed to read the word. In the second task the participants were presented with a series of Xs printed in different colors, and participants are instructed to name the color of the Xs. In the final, incongruent condition, participants are given a list of color words (e.g., green, red) printed in a different color, and the participant is instructed to name the color the word is printed in, which requires the greatest amount of interference control compared to the previous two tasks. Previous research in adults suggested that differences in performance between fit and unfit individuals were larger during tasks that require greater interference control. This difference was not observed in children. A significant effect was found for PACER scores in the first task, (partial correlation, controlling for all other variables (*pr*) = .38*,* $\beta$ = 0.34), the second, colored word task (*pr* = .27, $\beta$ = 0.25), and the final, incongruent task (*pr* = .31, $\beta$ = 0.30). The effect of aerobic fitness on task performance suggested that fit children performed better than unfit children, and the difference in performance was relatively similar in size during each task. The authors suggested increased fitness may be beneficial to cognition, though further testing is needed.

Chaddock et al. (2012) also found a relationship between aerobic fitness and cognitive performance. Their results included a one year follow-up to evaluate the long-term benefits of aerobic fitness on cognitive performance and enhance generalizability of the benefits. The researchers tested 9- and 10-year-old children, who were then classified by fitness level. The sample consisted of students whose $VO_2max$ was above the 70$^{th}$ percentile (higher-fit) and below the 30$^{th}$ percentile (lower-fit) determined by a maximal treadmill test. Children also had an MRI done to collect a structural brain image. To assess cognition, a modified flanker task was used, where the subject must respond to the direction of a target flanking arrow under different conditions and directions. This task requires the use of inhibition, cognitive flexibility, and working memory. Accuracy and reaction time to complete the task, which got progressively harder and required more cognitive control as the participant moved through the test, were recorded. Children who were classified as higher-fit were significantly more accurate than the low-fit children across compatibility task conditions and both at initial and one-year follow-up. Higher-fit children were able to maintain accuracy across conditions while lower-fit children became less accurate during more difficult conditions. Higher-fit children also had shorter reaction times than baseline at the one-year follow-up, while lower-fit children became slower than they were at baseline. MRI scans showed that higher-fit children had larger volumes in parts of the basal ganglia that are responsible for reinforcement, implicit, and category learning, as well as certain movements, than lower-fit children. The researchers suggested that fitness could have an impact on basal-ganglia volume and therefore brain-performance, particularly reaction time.

Many studies that have linked cognition and fitness have been comparative studies, unable to establish causality. Many potential confounders exist in such studies, and it is possible that certain children who have a predisposition to be more physically fit are also predisposed to have better cognitive abilities. Kamijo et al. (2011) examined the effects of an after-school activity program with heavy focus on moderate-to-vigorous physical activity of at least 70 minutes per session and some strength training on cardiorespiratory fitness and working memory. Study participants were 43 children aged 7-9 years, randomized into either the physical activity intervention program or a waitlist control group. The physical activity program occurred for two hours after school each day for one school year, and included activities that focused on improving cardiorespiratory fitness and on muscular fitness at least two days per week. Muscle strengthening activities included activities utilizing the participant’s own body weight and equipment such as Thera-bands and medicine balls. In a given day, children intermittently accumulated 70 minutes of moderate-to-vigorous physical activity, which was verified using a heart rate monitor. Students in the after-school program and the waitlist control group were tested at baseline to then see if several months later an increase in cardiorespiratory fitness measured by a maximal treadmill test would be associated with an increase in working memory, as measured by performance in the Sternberg Task. During the Sternberg Task students were to encode a memory set containing one, three, or five letters, and then press a button associated with the presence or absence of a single probe letter under different conditions. While they were performing the task, contingent negative variation event-related brain potential wavelengths measured via various electrodes were recorded. The authors observed that the physical activity intervention led to increases in cardiorespiratory fitness and improved Sternberg Task performance, with better response accuracy in those who improved cardiorespiratory fitness compared to those who did not improve their cardiorespiratory fitness. Reaction time did not differ among the physical activity and control groups. Greater benefits were seen in tasks requiring more usage of working memory, suggesting that fitness may be especially helpful in tasks requiring greater cognitive control.

The above studies examining fitness and cognition did not account for adiposity as a potential mediator. Children who are overweight or obese are also more likely to be below acceptable fitness levels (Aires, 2010), which could potentially affect cognition as well. In a study with 170 overweight, sedentary 7- to 11-year-olds, Davis and Cooper (2011) used the Cognitive Assessment System to test the children's abilities in four cognitive processes of planning (executive function), attention (focus, resistance to distraction), simultaneous (Gestalt processing), and successive (analysis or recall of a sequence). They also collected data from parents and teachers on the children's behavior, reading and math achievement, and had the children perform a treadmill test to assess fitness. Peak $VO_2$ was significantly and positively related to the planning ($r$ = .26) and attention ($r$ = .22) scales of cognition, while fatness was negatively related to planning ($r$ = -.22) and attention ($r$ = -.16). Peak $VO_2$ was also positively related with reading ($r$ = .29) and math ($r$ = .25) achievement, while body fat was negatively related to reading ($r$ = -.20) and math ($r$= -.23) achievement. Relationships with fitness, regardless of fatness, were found with teacher ratings of behavior. The authors suggested that fitness, regardless of adiposity level, is slightly related to certain aspects of cognitive function and both reading and math achievement. Given that physical activity has an important role in increasing fitness levels, the authors suggested that more research is needed to investigate physical activity levels, instead of just body composition and cardiorespiratory fitness, to determine if physical activity alone may be related to cognition.

Many of the physical activity interventions designed to improve cognitive function intended to assess whether increases in physical activity and/or fitness levels result in improved cognitive function. Some programs, however, may have either simultaneously or alternatively been measuring the effects of an acute bout of exercise. For example, in a before school physical activity program described in an abstract by Mahar et al. (2011), cognitive function tests mid-intervention were conducted after the program ended on the testing days. It is possible that any acute (short-term) effects of physical activity may have still been in effect from the time spent being active at the program. This means that any improvements from baseline may have been from the physical activity intervention and increases in regular, daily physical activity, but they may also have been due to the acute benefits of the physical activity bout that had been performed just a short time before.

Hillman et al. (2009) examined the effect of acute treadmill walking on cognitive control in children, as measured by a modified Flanker task. Electroencephalographic (EEG) activity was recorded from 64 electrode sites. This study used a within-subjects design, with participants tested on two different days after either 20 minutes of seated rest or 20 minutes of aerobic exercise. Participants were assigned to the two experimental conditions in a counterbalanced order, receiving the alternate treatment on their second visit. The analysis for reaction time showed non-significant differences between the acute exercise and rest conditions. Regarding response accuracy, however, participants showed increased response accuracy following acute exercise relative to rest only during incongruent Flanker task trials. Components of event-related brain potentials (ERP) as measured by the EEG showed that they were affected by the acute bout of treadmill walking, with P3 amplitudes being larger after the walking condition. The P3 is a positive component of the ERP that is believed to reflect attention to stimuli and processing speed, with larger amplitudes indicating increased attentional resources being allotted toward a stimulus. The authors concluded that an acute bout of moderately-intense aerobic exercise resulted in improved P3 amplitude, showing more attention to the task, and increased response accuracy. The lack of a relationship between acute exercise and children's reaction time during the flanker task was attributed to the children being more impulsive in their task completion.

Available research suggests that enhanced cognitive functioning may be one reason to support increased physical activity for children, and that, at the very least, physical activity will not negatively impact cognitive function. If enhanced cognitive function is a result of an acute bout of physical activity, then the school setting is an optimal location for increasing activity levels.

**School-Based Physical Activity**

The public is becoming increasingly alert to the need to advocate for physical activity, and several groups have begun to commit to making physical activity a priority. Schools are an optimal location for promoting physical activity in young populations due to their safe environment, accessibility, and the ability to reach so many individuals conveniently. Because some children may lack the resources or ability to accumulate physical activity time outside the school day, the school setting may be the only option for these children to participate in physical activity. Physical activity has not been shown to negatively affect academic achievement, even when academic classes are cut. In a systematic review of physical activity interventions for school-aged youth, Strong et al. (2005) highlighted studies that suggested a positive increase in academic performance per unit of time increased in physical activity. The authors also concluded that physical activity has a positive influence on behavior, concentration and memory, and intellectual performance. Studies across the United States show agreement, with grades, behavior, attendance, test performance, and other academic achievement variables being positively or at least not negatively affected by increased physical education and/or physical activity levels.

In a cross-over study, Coe, Pivarnik, Womack, Reeves, and Malina (2006) measured the effect of enrollment in physical education during a semester and the relationship with both physical activity levels outside of school and academic achievement in 214 sixth-grade students. All students were randomly assigned to physical education during their first or second semesters. MVPA outside of school was measured using the 3-day physical activity recall for children, and was reported in 30-minute time blocks. Children were then coded a score of 1 (no activity), 2 (some activity), or 3 (activity meeting Healthy People 2010 guidelines). Academic achievement was based on individual grades in the four core classes of English, mathematics, science, and world studies, as well as a standardized test score. The authors observed that timing of physical education did not have an effect on any of the measures of academic achievement, however, children who performed vigorous physical activity at least at the level recommended by Healthy People 2010 guidelines achieved higher academic scores compared with students who did not get recommended amounts of vigorous activity during both the first and second semesters. The authors concluded that children who met recommended activity levels for vigorous physical activity had higher academic scores than children who did not accumulate enough vigorous activity to meet recommendations. Also, enrollment in physical education class did not influence academic achievement in any of the core classes, suggesting that enrollment in physical education does not negatively impact academic performance.

Grissom (2005) compared standardized test performance and physical fitness scores by using available California standardized test and physical fitness test scores of 5$^{th}$, 7$^{th}$, and 9$^{th}$ grade students. Physical fitness scores included scores in six aspects of fitness including aerobic fitness, body composition, abdominal strength, trunk strength, upper body strength, and flexibility. For analysis purposes, children were given a score from 0, indicating no tests passed, to 6, which meant passing all fitness tests. Standardized test performance was higher for students who performed better on the six physical fitness tests than those who did not perform well on the fitness tests. The relationship between fitness level and California standardized test performance was positive, with average scores in each subject area increasing with each additional test passed. The change in average score from those who failed all fitness tests to those who achieved fitness standards in all tests was around 50 points for both mathematics and English-language arts. When analyzing the data by gender, the relationships between fitness scores and test scores were similar for females and males, though the rate of change was larger for females than males, with females scoring about 9 points higher with each additional fitness test passed and males scoring about 6 points higher with each additional fitness test passed. Also, when split by socio-economic status, the relationship was stronger in those of higher socio-economic status than in those with lower socio-economic status. The difference in standardized test scores between those who failed all fitness tests and those who met all fitness test requirements was about 50 points for those identified in the study as being of high socio-economic status, but only about 25 points for those identified by the study as being of low socio-economic status. This study suggests that overall fitness, not just aerobic fitness as measured in many other studies, has a positive relationship with standardized test scores. Unfortunately, because the data were taken from school district records and no further information from the sample were analyzed, the data cannot indicate a cause-and-effect relationship. It cannot be concluded whether or not overall fitness has a positive effect on standardized test scores, only that a relationship between fitness and standardized test scores does exist.

Welk et al. (2010) examined data from the Texas Education Agency on 2.4 million Texan students (75% of all schools in Texas) from the 2007-2008 school year. The data included test scores, attendance, reported disciplinary problems, and student fitness levels measured by the *FITNESSGRAM*. Data were aggregated within each school by grade and gender to allow for comparisons because individual data were not tracked by the state to ensure confidentiality. Data were then analyzed to determine if schools with more students at satisfactory levels of cardiorespiratory fitness and body composition were more likely to have students achieve age-specific test score standards, have better attendance, and if they would be reported as being better behaved, with fewer disciplinary problems than less physically fit students. Correlations were examined among study variables to determine general relationships. Healthy Fitness Zone achievement in the *FITNESSGRAM* for aerobic fitness was significantly correlated with body composition Healthy Fitness Zone rates ($r$ = .36). Low to moderate correlations were observed between cardiovascular fitness and test performance ($r$ = .41), attendance ($r$ = .38), and delinquency ($r$ = -.47). Lower but still significant correlations were found between body composition and test performance ($r$ = .24), attendance ($r$ = .17), and delinquency ($r$ = -.26). Schools that were classified by the state as being "high-performing" had about 80% of students with healthy cardiorespiratory fitness levels. In the schools that were labeled by the state as academically unacceptable, just over 40% were meeting cardiorespiratory fitness levels for acceptable health. This study suggested that both body composition and aerobic fitness may relate to performance in school, and the relationship may be stronger for aerobic fitness than for body composition.

Even though allowing more time for physical activity during the school day may lead to positive academic outcomes, reported data from certain state school systems suggest that physical activity time at school is poorly mandated. According to data published by the National Association for Sport and Physical Education (2012), only 18% of reporting states mandate 150 minutes per week or more of physical education in elementary school (average of 30 minutes per day). Forty-four percent of reporting states require less than 90 minutes per week of physical education. These minimal time requirements provide even less guidance on how much of the time in physical education should be spent actually being active.

With the lack of required time for physical education, it is important to make the most of the time that is available. However, most children do not spend much of their physical education time in moderate-to-vigorous physical activity. In a sub-study of the National Institute of Child

Health and Human Development Study of Early Child Care and Youth Development, researchers went into elementary schools across the country to observe a diverse group of third-grade students in their physical education classes (Nader, 2003). On average, children participated in physical education lessons 2.1 times per week, for an average of 68.7 minutes per week. Over 75% of the children had physical education only once or twice per week, and children who did not get any physical education weekly were not included. Overall, a total of 11.9 minutes of MVPA were accrued per physical education session, of which 4.8 minutes were considered “very active.” This showed that, per week, students only accumulated 25 minutes of the recommended 420 minutes per week of physical activity during physical education sessions. While slight differences were seen between boys and girls, with boys sometimes accumulating more MVPA time, on average, all children spent 61.9% of their time during physical education sitting or standing without moving. It should be noted when interpreting this study that an observation of “walking” (regardless of speed) was counted as moderate activity and anything above walking was considered “very active” or vigorous activity. In reality, the intensities may have been lower, such as a light walk or light jog, which may have caused an over-estimation of the already low number of minutes of MVPA reported.

As part of their physical activity objectives, Healthy People 2010 set a goal of spending 50% of physical education time in moderate-to-vigorous physical activity (U.S. Department of Health and Human Services, 2000). Evaluations of this goal have found that most physical education programs are far off of this number, and due to the lack of a national data source to measure how time is spent in physical education, this goal was archived and is not included in current Healthy People goals. This means that without policy support to improve the quantity or quality of physical activity time in schools, physical activity interventions may be better focused outside of the school day.

With little time is mandated for physical activity during the school day, it is important that educators use the little time that is allocated for physical activity as effectively as possible, and encourage children to be active. This may not always occur, and it is possible that despite program goals much of the time allotted for physical activity is actually spent with children being sedentary. For example, Ridgers, Fairclough, and Stratton (2007) showed that MVPA time during recess in their sample varied from 21-33%, with significant differences between boys and girls. Only 4.5-7.0% of the children's recess time was spent in vigorous physical activity.

Efrat (2013) tested different methods of promoting physical activity during recess that could be carried out by faculty at the school. Qualified adults modeling activity did not increase MVPA time accumulated by children during recess as measured by accelerometer. Social prompting by adults, who were encouraging students to engage in active behaviors, increased MVPA time by an average of 2.41 minutes per 20 minute recess period, or by about 12%. Efrat suggested that modeling may not be effective because it does not target a child's active choice to engage in physical activity, and that interventions designed to increase MVPA should not focus on already structured physical activity time, but rather on times where children can choose to be active or not.

In a review paper, Burton and VanHeest (2007) discussed the importance of physical activity in closing the persistent achievement gap between African American and Hispanic students when compared with White and Asian students. The authors noted that African American and Hispanic students are disproportionately more likely to be overweight, which may be related to health and self-esteem, and that a logical approach to combat childhood overweight is to teach healthy physical activity behaviors, which are mostly done in physical education. Unfortunately, due to pressures to increase test scores at a young age, schools are contributing to the culture of inactivity by decreasing time for both recess and physical education and in some cases making extreme cuts in time allotted for one or the other. According to the authors, pressure for increases in standardized test scores, and to decrease the achievement gap, lead teachers to narrow their curriculums to focus on details that will be on these tests. Urban school districts struggling to meet accountability standards may be disproportionately impacted by the narrowing of the curriculum. Reduction in physical activity opportunities may inadvertently contribute to the overweight problem in a population that is already struggling. However, as seen in several of the previously mentioned studies, Burton and VanHeest briefly explain that physical activity and/or fitness is positively related to performance in school. Despite the link between physical activity and reductions in overweight, decreased health risks, improved cognitive functioning, and improved academic outcomes, schools are constantly narrowing their subject areas to focus on content found on standardized tests, and physical education is often one of the subject areas in which schools have reduced time. Cutting physical education and physical activity time is likely counterproductive in producing the desired outcomes. The authors suggested that policy makers and educators take time to educate themselves and realize the positive impacts physical activity behaviors can have on academic achievement, and on preventing the downward spiral that may occur if the counter-productive actions of cutting activity time are continued.

While great effort has been put forth to increase physical activity levels in after-school programs, research has shown that these programs are not very successful, and students only engage in approximately 20 minutes of moderate-to-vigorous physical activity during such programs, despite often being at these programs for several hours (Trost, Rosenkranz, & Dzewaltowski, 2008). While success in after-school programs has been limited, research on active commuting to school or other physical activity before the school day has shown potential to increase activity levels during a time when children can choose whether or not to be active. Before school programs are a new, under-researched area in need of further investigation.

The pressure to spend more time in academic classes during school hours, along with busy schedules at the end of the school day make it difficult to target physical activity interventions at large groups of children during those times. Programs that encourage physical activity before the school day begins are a promising answer. Few studies have focused on before school programs. One of the methods to accumulate MVPA before the school day has been through active commuting. Active commuting includes both walking and biking to school, and can have several benefits. Children who have at least a 15 minute commute to school can accumulate a good amount of their activity before the school day even starts, and active commuting has been shown to be related to both adiposity and cardiorespiratory fitness (Aires et al., 2011).

Martinez-Gomez et al. (2011) found that in a sample of 1,700 adolescents, active commuters who were female had better cognitive performance scores in verbal, numeric, and reasoning abilities than non-active commuters, independent of confounders. No differences were found among boys. Boys in their sample had significantly higher cognitive performance than girls, which may have made it more difficult to find differences among those who commuted and those who did not. The researchers suggested a dose-response relationship between time spent actively commuting each day and benefits received by girls, with those who commuted more than 15 minutes to school scoring better on three of the four measured cognitive performance variables. This study failed to establish cause-and-effect, but did suggest the possibility that being active in the morning can impact cognitive function.

Research on before-school physical activity programs is currently scarce. One of the only studies to look at a structured before school physical activity program observed that children were more attentive and increased on-task behavior by 18% throughout the school day from baseline to intervention, and also did not decrease their physical activity levels throughout the day (Mahar et al., 2011). These effects diminished at post-intervention, highlighting the importance of maintaining the before school program throughout the school year. The children were also tested using the CogState assessment system to identify if physical activity before the school day had any effects on cognition (visual attention, processing speed, working memory, and learning). Executive function and working memory improved from pre-intervention scores, but these effects did not return to baseline with removal of the intervention.

Thompkins, Hopkins, Goddard, and Brock (2012) in a method paper described the future methods of their 12-week program that intends to meet three times a week for 45 minutes before school. Their program will be unstructured and focused on free-play where children are free to choose their own activities. The authors provided rationale for unstructured time stating that MVPA is higher during free-play than during structured play time. Allowing free play may also promote the regular behavior of children choosing on their own to be physically active. Heart rate will be monitored three times per session, and children will be encouraged to play at a moderate or vigorous intensity. Anthropometrics, blood pressure, academic performance, physical activity, eating behavior, health-related quality of life, and feelings/emotions will be evaluated using questionnaires.

**Summary**

Current physical activity recommendations are for children to accumulate 60 minutes of physical activity each day, with muscle-and-bone strengthening activities on 2-3 days per week. Studies that have employed both subjective (Eaton et al., 2012) and objective (Troiano et al., 2008) measures of physical activity show that many children are not meeting these recommendations. In addition, a large percentage of students are classified as unfit in one or more of the health-related components of physical fitness, and 50% or more students fail upper body strength and endurance tests regardless of BMI category (Aires et al., 2010).

Muscle- and bone-strengthening activities utilizing body weight or traditional resistance training using free weights or machine weights has been shown to be safe and effective for children of a variety of ages when proper form is emphasized and supervision is provided (Faigenbaum et al., 2009). Resistance training programs using different exercises, program lengths, and those composed of either resistance training alone or in combination with other health-promoting interventions have suggested that children of all ages may benefit from a resistance training program. Children who engage in resistance training programs may benefit by improving their body composition, increasing lean body mass, increasing muscular strength and endurance, stimulating healthy bone growth, improving insulin sensitivity, and increasing confidence in their physical abilities (Eiholzer et al., 2010; Heidemann et al., 2013; Van der Heijden, 2010; Yu et al., 2008.) Therefore, any physical activity program geared towards children should include a resistance training program to stimulate bone and muscle growth.

Physical activity may also improve psychological variables, such as physical activity self-esteem and self-efficacy (Annesi, 2006; Annesi, Wescott, Faigenbaum, & Unruh, 2005; Ekeland, Heian, & Hagen, 2005; Parfitt & Eston, 2005; Sung et al., 2004; Yu et al., 2008), physical activity enjoyment (Moore et al., 2011), and various domains of cognitive function. Cognitive function benefits gained from physical activity may be a factor of particular interest to school officials, who have recently trended toward cutting physical activity time in favor of more academic time (Burton & Vanheest, 2007). Physical activity and/or physical fitness levels have been shown to be positively correlated with or have no impact on academic achievement (Coe et al., 2006; Grissom, 2004; Hillman et al., 2008; Hillman et al., 2009; Welk et al., 2010) and may impact different domains of cognition (Buck et al., 2007; Chaddock et al., 2010; Haapala, 2013; Hillman et al., 2009; Kamijo et al., 2011; Martinez-Gomez et al., 2011). This suggests that rather than cutting physical education and physical activity time at school, schools should focus on finding more ways to allow their children to accumulate physical activity, to potentially positively impact cognition, and at the very least to give them a break from their academic curriculum.

The school environment is an optimal location for targeting children and creating more opportunities for them to be active, since children spend several hours at school each day and schools provide access to multiple children in a relatively safe location. At school, physical education classes are sometimes the only opportunity available for certain children to participate in physical activity. Despite this, physical education is minimally mandated, with larger requirements still not adding up to enough total minutes per week for children to meet recommendations, and physical education in many school districts is not regulated at all (National Association for Sport and Physical Education & American Heart Association, 2012). Even in school time that is designated for physical activity, such as in physical education, children may only accumulate around 10 minutes of MVPA per session (Nader, 2003). Some physical activity interventions have focused outside of the school day, in hopes of finding other times where children may accumulate MVPA. While many physical activity interventions at school have focused on after school hours, research on before-school physical activity programs is scarce. Programs focused before the school day may be a promising, novel approach to increasing children's physical activity levels, and the timing may allow acute benefits of a physical activity bout, such as those on cognition, to continue into part of the school day.

Current available research, therefore, suggests that increasing physical activity levels and/or physical fitness can provide children with multiple benefits during a time when they are growing and developing habits that will persist for the rest of their life. Physical activity interventions for children scheduled before the school day begins may be a great way to increase physical activity levels during a time when children may otherwise be sedentary. Furthermore, any cognitive benefits that might be temporarily gained from a bout of physical activity would be most convenient to elicit before school begins, in hopes that the acute effects on cognition from physical activity might persist into the school learning time. Any physical activity programs designed for children should emphasize both aerobic and muscle- and bone-strengthening activities, so as to meet USDHHS (2008) physical activity guidelines. Younger children may be the most desirable population to intervene with, as physical activity interests and habits may not yet be fully developed in this age group.

## Methods

### Participants

Participants for this program were 42 children (ages 7-10 years) recruited from third grade classes at an elementary school in eastern North Carolina. In the school where the program was held, 71% of children received free or reduced-price lunch. School demographics were as follows: 63% African American, 26% White, 5% Hispanic, 5% mixed race, and 1% Asian. Letters were sent home from the school to all parents/guardians of children in all four of the third grade classes (approximately 77 total students) describing the program and a brief overview of the outcome goals. Parents were asked to return a consent form with their child to school indicating their interest in the program. The first 40 children to return consent forms were invited to participate in the program. An additional 2 children were added to the roster after parents contacted the school and research team requesting that their child be enrolled in the program. All program participants provided assent to participate. Of those who returned consent forms, 74% of children received free or reduced-price lunch. Demographics of the children who returned consent forms were as follows: 62% African American, 17% White, 5% Hispanic, 7% mixed race, and 9% unknown race. Children were considered to be regular attendees at the program if they attended the program on at least 70% of the program days, which would mean they attended the program on more than 30 of the days it was held.

### *First-Class* Before-School Activity Program

Prior to the start of the program, research assistants attended between 4 and 5 orientation meetings. These meetings were designed to help research assistants understand how to work in the school environment, how to lead and assist children with physical activities, and how to use equipment and carry out assessments. In addition, research assistants were provided information about physical activity motivation in children and about what was expected of them on days they were to lead activities. Practice administering all muscular strength and endurance assessments was provided.

The *First-Class* Before-School Activity Program took place Monday through Friday, for approximately 25-30 minutes before the school day began in the elementary school's multi-purpose room on each day school was in session for 10 weeks between the end of September and the beginning of December during the fall 2013 semester. The program was free of charge. Daily attendance at the program was encouraged, but not required. Children were informed that the program was physical activity-based and that they needed to be active if they were to attend the program on a given day. If children were not being active, they would be approached by a research assistant and encouraged to engage in the activities.

The program had two parts. Children were first permitted to enter the multi-purpose room at 7:15 every morning. For the first 10-15 minutes of the program, children came in as their parents dropped them off and buses arrived. During these first 10-15 minutes, children generally had "free-play," during which time they were encouraged to be active on their own with the research assistants and each other. Jump ropes, sports balls, and hula-hoops were the most commonly used items during this time. The second part of the program generally began around 7:30 and went until about 7:40 when the students were required to be dismissed for breakfast. This part of the program included an organized activity planned by a different research assistant each day. These activities were planned ahead of time and the person creating the activity each day was instructed to have his or her activities focus on aerobic activity and muscle- and bone-strengthening activities. Attempts were made to include muscle- and bone-strengthening activities on at least 3 days per week, and aerobic activity was included every day, as recommended (USDHHS, 2008). Upper body strengthening activities were emphasized because many children are unable to achieve the Healthy Fitness Zone for upper body strength, regardless of weight status (Aires, 2010) and because low strength was perceived in most of the children by the physical educator at the school. Equipment was provided both by the elementary school and by the researchers, and was selected to allow for both aerobic and resistance exercises. Equipment used during structured activity time included jump ropes, hula-hoops, sports balls, small and large exercise balls, resistance tubing, and various other objects. Circuit training exercises, obstacle courses, and other games that required all or most of the children to be moving at any given time were incorporated into the program.

**Measurement Procedures**

Unfortunately, due to limitations of a school-based intervention design, time was limited each day and children could not be kept for the extra time needed to carry out assessments once the school day started. While the researchers of this study originally intended to measure each variable pre- and post-intervention, the 25 minute time constraint each morning did not allow for that volume of data collection. Therefore, each outcome variable was not measured at the same time. Time restraints allowed anthropometric data, physical activity enjoyment, and physical activity self-efficacy to only be measured once instead of twice as originally planned. Children were measured on different domains of cognitive function, certain anthropometric measures, physical activity levels, upper body strength, endurance, and power, exercise self-efficacy, and physical activity enjoyment. The data collection timeline for the *First-Class* program is presented in Figure 1.

Figure 1

*First-Class* Before School Program Data Collection Timeline

<table>
<tr><td></td><td colspan="10">Intervention Week</td><td></td></tr>
<tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>Post Intervention</td></tr>
<tr><td rowspan="5">Consent Forms</td><td colspan="10">First Class Before School Program</td><td rowspan="2"></td></tr>
<tr><td>Practice</td><td colspan="2">CogState - No Physical Activity Condition</td><td colspan="4"></td><td colspan="2">CogState - Physical Activity Condition</td><td></td></tr>
<tr><td colspan="2">Anthropometric Measurements</td><td>Accelerometer Data Collection</td><td colspan="2"></td><td colspan="2">Questionnaire Administration</td><td colspan="3"></td><td>Accelerometer Data Collection</td></tr>
<tr><td rowspan="2"></td><td colspan="3">Pedometer Data<br>Early Intervention</td><td colspan="3">Pedometer Data<br>Mid-intervention</td><td colspan="3">Pedometer Data<br>Late Intervention</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Upper Body Strength</td><td colspan="4"></td><td colspan="2">Upper Body Strength</td></tr>
</table>

**Anthropometric Measurements.** Height was measured to the nearest half centimeter with a measuring chart attached to the wall in the multi-purpose room and weight was measured to the nearest fifth of a pound with a portable scale (Health-o-Meter model 349KLX Medical Scale, Bridgeview, IL). Body mass index (BMI) was determined by dividing weight in kilograms by height in meters squared and BMI percentile was determined.

Percent body fat was assessed with triceps and calf skinfolds. This two-site method is commonly used in children as it is less invasive than the other skinfold measurement sites. Skinfolds were measured twice at the triceps of the right arm and calf site of the right leg with Lange calipers (Cambridge, MD). If the two measurements were greater than 2 mm apart, a third measurement was taken. One female research assistant assessed all skinfolds for girls and one male research assistant assessed all skinfolds for boys. Percent body fat was estimated from skinfolds with the equations of Slaughter et al. (1988) as shown below.

Boys: Percent Body Fat = 0.735 (triceps + calf) + 1.0

Girls: Percent Body Fat = 0.610 (triceps + calf) + 5.1

The triceps skinfold is measured on the back of the right arm over the triceps muscle, midway between the elbow and the acromion process of the scapula. The calf skinfold is measured on the inside of the right leg at the level of maximal calf girth. The right foot is placed flat on a box with the knee flexed at a 90° angle. The median values of the two closest measurements were used for calculations.

**Physical Activity Assessment.** Physical activity was assessed two ways. Physical activity was assessed each day during the program using step counts from an Accusplit Eagle 120 XLE pedometer. Upon arrival to the program each day, each child’s time-in was noted. Children were then assigned a pedometer. Pedometers were typically worn on the right side in line with the midline of the thigh, attached by a clip to the top of the child's pants. In some cases, the pedometer was worn on the right side lateral to the midline of the thigh or in a different location. This occurred if the pedometer could not remain upright in the normal position, or if the child was wearing a dress that day. When children left the program each day for class, pedometers were collected and researchers noted the time the pedometers were taken off. Step count and activity time were recorded from the pedometers, and a wear time value was recorded based on when the child arrived to the program that day.

Physical activity was also assessed during the school day using ActiGraph accelerometers (model GT3X+, ActiGraph LLC, Pensacola, FL). Previous research has shown ActiGraph accelerometers provide a valid measure of physical activity in children (Trost et al., 1998). School day physical activity levels were compared between a week of measurement during participation in *First-Class*, and a week post-intervention after the program had ended. School day physical activity refers to activity accumulated during the time period of 7:45 a.m. to 2:00 p.m. Time during the *First-Class* program was not included in the school day physical activity analysis. Participants were only included in the analysis if they had 180 minutes or more of wear time on a given day.

Percent of time in sedentary, light, moderate, and vigorous physical activity was also measured for four days during the program using ActiGraph accelerometers to assess the intensity of the participants' activity while at the program. Physical activity levels during *First-Class* were also determined. For the time in *First-Class,* the accelerometer measured activity accumulated from 7:15 a.m. to 7:45 a.m. In addition to adding this time filter, log diaries were imported into the ActiLife program to specify the time each morning that each participant arrived to the program and put on an accelerometer. This would prevent activity from being counted that may have been picked up from moving the accelerometers around before the child actually arrived at the program.

Students wore an accelerometer every day they were present for four consecutive school days during the *First-Class* program and for five consecutive school days after the *First-Class* program ended. If children were late and/or missed the program on a data collection day, they were still given an accelerometer once they arrived to their classroom to measure their activity during the school day. Accelerometers were placed on the student upon arrival at school (or upon arrival to *First-Class* during the intervention period if they attended) and removed at the end of the school day. Proper placement of the accelerometer is on the right hip in line with the midline of the thigh, attached to an elastic belt. Each student was assigned an accelerometer to use throughout data collection. During the intervention period, students were given the accelerometer as soon as they arrived to the program, or to school. Post-intervention, the accelerometers were given to the students at the beginning of the school day.

Epochs were set at 1-second intervals. Activity was classified as sedentary behavior, or light, moderate, or vigorous intensity activity using the cutpoints established by Evenson et al. (2008). Percent of total time spent in each level of intensity was calculated.

**Muscular Strength, Endurance, and Power Assessment.** Muscular strength, endurance, and power were assessed early (weeks 2-3) in the program and late (last two weeks) in the program. Due to the time required to perform these assessments, attendance, and the limited number of research assistants, the assessments during each time period were done at some point over a 2-week period early, and late in the program. The FitnessGram protocol to assess upper body strength via the push-up test (Plowman & Meredith, 2014) was used. Upper body power was assessed using a seated, 4-pound medicine ball toss. Evidence of validity and reliability of this test has been shown in young children (Davis et al., 2008). Students sat with their back against a wall, feet about 2 feet apart, with the ball against their chest and their elbows out, and were instructed to throw the ball as far as they can while following the test protocol, which involved keeping their lower body stable and using only their upper body. Students were given as many practice trials as needed until good form was shown. During scored trials, children were instructed to continue until two trials with good form were performed and recorded.

Handgrip strength was assessed using a Lafayette hand dynamometer (Model 78010, Lafayette, IN). Participants were instructed to grip the dynamometer while holding their arm at a 90 degree angle, and to maintain that angle while they performed trials. Participants were permitted to ask that the dynamometer handle be adjusted for a more comfortable grip. They were instructed to squeeze as hard as they could for two seconds, and then relax. Handgrip strength in kilograms was recorded to the nearest half-kilogram. Two trials were given for each hand, alternating between the two hands to allow for rest. The average of the two trials was used in the analysis.

**Cognitive Function Assessment.** Cognition was assessed using the CogState computerized assessment system. The CogState system contains different tests to assess various domains of cognitive function. These tests were designed to allow for multiple assessments in a short period with little to no practice effects. The CogState assessment system has been used with healthy children to analyze attention, working memory, spatial memory, and executive function. Previous studies have used the CogState battery with children aged 8-10 years (Kral, Heo, Whiteford, & Faith, 2012). The test-retest reliability of the CogState assessments have been established in 8- to 12-year old children when assessed multiple times in the same day (Mollica, Maruff, Collie, & Vance, 2005). While there are 13 total tasks, typically only a subset of the tasks is administered in any particular study. For a brief battery or to assess only specific outcome variables, certain tasks may be selected alone or in combination with others to meet the needs of the researcher. For this study, in the interest of time and based on what the review of cognition literature suggests may be related to physical activity or physical fitness, three tasks were chosen.

The CogState program presents stimuli on a computer screen and participants respond to the stimuli depending on the rules of each task. For example, one measure of working memory presented images of playing cards and asked participants to respond yes or no to the question ‘Is the previous card the same?’ Children were given sufficient practice during the first week of the program, and were not given their baseline test until one of the researchers had supervised a full “good practice.” A “good practice” was a practice where the participant was perceived as focused and undistracted, as putting forth good effort, and the participant was able to recall on his or her own or with little guidance how to perform each task. The total test consisted of three cognitive function tasks, presented in the same order each time.

The first task was the Groton Maze Learning Task, which assesses executive function and spatial problem solving. In this task, participants are instructed to find the 28-step hidden pathway among 100 tiles. To start, the participant clicks on a box in the upper left corner of the maze. Then, they must click up, down, left, or right to find the hidden pathway. With each correct move the participant sees a green check and may move on to the next box. With each incorrect move the participant sees a red “X” and must return to the last correct box. The goal is to make it to the bottom right corner. They then are presented with the same hidden pathway and must repeat the task. The participant first does a small, practice maze three times, and then progresses to the actual task, which has five rounds of a larger maze. Participants' data were only used if they completed the task. According to Cogstate, completion of the Groton Maze Learning Task meant that they completed all 28 steps in the maze path for rounds 1-5, which meant a total of 140 completed steps over all five rounds.

The second task was the One Back Task, which assesses attention and working memory. In this task, the participant is presented with a card. That card then disappears. When the next card appears, the participant must decide if the current face up card is the same as the card he or she just saw. That card then disappears, a new one appears, and participants must continue to answer the same question as yes or no. Integrity checks suggested by CogState (2014) were conducted on the data, which required that participants meet minimum accuracy score criteria. This meant that participants must have had an accuracy score of .785 or higher. Participants who did not pass the integrity check were excluded from the analyses.

Finally, the participants were presented with the Continuous Paired Associate Learning (CPAL) Task, which assesses visual learning and memory. In this task, participants first learn the locations of different shapes by clicking on them in the periphery of the screen when they appear as the center object. Then, the shapes on the periphery are hidden, and participants must attempt to remember the location of the shapes as they appear in the middle. Participants are allowed to keep clicking spots on the screen until they answer correctly where the shape belongs. Participants were given one presentation trial to learn where all shapes belong, followed by six learning trials, where the participant repeats the same task with shapes hidden in the same locations six times. Participants' data were only used if they completed the task. Completion of the CPAL task meant that they completed 12 steps in each round, for a total of 56 steps over 7 rounds.

According to CogState (2014), in healthy individuals these tasks take 5, 2, and 5 minutes, respectively. After a trial on some young participants prior to the program, it was estimated that the tasks would take about 15 minutes altogether. All three tasks were performed on two different occasions for comparison, the first week they attended the program (baseline) on a day they did not participate in any physical activity at the program, and during one of the last 2 weeks of the program after they had been at the program for at least 10 minutes and accumulated at least 750 pedometer steps. The pedometer requirement was used to ensure that the participant had spent a significant amount of time engaged in physical activity at the program during those 10 minutes.

**Psychological Variable Assessment.** Psychological variable questionnaires were assessed in small groups of no more than eight children, where a researcher read the questions and participants circled the appropriate answer on their sheet. Exercise self-efficacy was measured with the self-efficacy scale, which was validated in children by Saunders et al. (1997). This is a 14-item questionnaire for which the respondents answer “yes” if they think they can overcome a certain barrier and be physically active, or “no” they cannot. The self-efficacy scale examines factors of support seeking, barriers, and positive alternatives to exercise. The Support-Seeking subscale asks whether or not the respondents believe they have the ability to ask others to help them to be physically active, such as if they can ask their parents to take them to be physically active or the belief that they can ask others, such as friends, to be physically active with them. The Barriers subscale asks whether or not the respondents believe they can be physically active in the face of common barriers to physical activity for children, such as if they have a lot of homework. The Positive Alternatives subscale asks whether or not the children believe they can be physically active when other, more appealing alternatives might be available (e.g., watching TV). Scale scores were created by summing the items forming each subscale. A score of 1 was given for questions answered “yes” and a score of 0 was given for questions answered “no”, as done in previous research (Trost et al., 1997). Subscale scores ranged from 0-7 for support seeking, 0-4 for barriers, and 0-3 for positive alternatives.

Physical activity enjoyment was measured using the Physical Activity Enjoyment Scale (Kendzierski & DeCarlo, 1991) and modified for use with a third grade population. This 16-item questionnaire uses a 5-point Likert scale on which participants determine whether or not they “disagree a lot” (1) or “agree a lot” (5) or fall somewhere in between with each statement. Due to time restraints, these questionnaires were only administered once to each child in week seven of the program and took 20-30 minutes. The program was ended early on that day to administer the questionnaires.

The Physical Activity Enjoyment Scale, in this study, was not useful. Participants often selected one extreme or the other, and may not have understood some of the questions. Oftentimes, participants would select opposite answers for similarly-worded questions, leading the researchers to believe that the participants either did not understand the question or did not have the patience to take the questionnaire seriously. Also, possibly due to the congestion of the paper, participants would sometimes circle two answers for the same question, and/or miss others. This may be due to slight carelessness by the participants, or because the questionnaire’s layout was not appropriate for this age group. Due to these issues with the Physical Activity Enjoyment Scale, large portions of the data were missing. This led the researchers to believe the data are likely unreliable, making it impossible to draw any conclusions from the questionnaire. For this reason, data from the questionnaire were not presented in the results or discussion.

**Statistical Analysis**

IBM SPSS version 20 was used for statistical analyses. Total steps as well as steps-per-minute at the program were calculated from daily pedometer data. Repeated measures analyses of variance (ANOVA) were conducted to examine differences in pedometer steps at the program between early intervention, mid-intervention, and late intervention. Repeated measures ANOVA were conducted on accelerometer data to examine differences in sedentary behavior, differences in light, moderate, and vigorous physical activity, and differences in steps per minute between one week while the program was in session and one week post intervention. For musculoskeletal fitness tests, the mean of trials at each time point (except for push-ups) was calculated and a paired-samples *t*-test was used to examine differences from early to late intervention. Cognitive function was analyzed using repeated measures ANOVA to examine differences in errors made during the Groton Maze Learning Task, the One Back Task, and the Continuous Paired Associate Learning Task on days participants engaged in at least 10 minutes of activity at the program compared with days children did not attend the program before taking assessments. Effect sizes (*ES*) were calculated using Cohen's delta to estimate the size of the mean differences between early intervention and late intervention data collection periods. Physical activity self-efficacy was scored by summing the total number of "yes" answers in each of the three subscales. The mean score of all participants who answered every question in each given subscale were averaged.

## Results

Forty-three children returned consent forms and provided assent to participate in the *First-Class* program. Of these 43 children, 4 never attended the program, and 1 child moved out of the area after week 4 of the program, leaving 38 total participants who were enrolled in the program for the entire duration. The *First-Class* program was held on 44 days over 10 weeks. Of the 38 children who attended at some point over the 10-week program, 28 of the children attended the program on at least 70% of the days it was held. Attendance on at least 70% of the days meant that children were present for 30 or more days. Data presented below are only from children who attended 30 or more days. Descriptive statistics are provided in Table 1.

Table 1
Descriptive Statistics

| | Boys *n = 12* | Girls *n = 16* |
|---|---|---|
| | *Mean* ± *SD* | *Mean* ± *SD* |
| Age (years) | 8.7 ± 0.5 | 8.5 ± 0.6 |
| Height (cm) | 136.6 ± 5.9 | 136.5 ± 4.9 |
| Weight (kg) | 33.3 ± 4.0 | 35.6 ± 11.2 |
| BMI (kg/m²) | 17.9 ± 2.0 | 18.6 ± 4.7 |
| Percent Fat (%) | 18.5 ± 5.1 | 21.7 ± 7.7 |
| Self-Efficacy Subscale Scores | | |
| Support Seeking | 6.2 ± 0.8 | 5.7 ± 1.5 |
| Barriers Self-Efficacy | 3.0 ± 1.2 | 2.6 ± 1.3 |
| Positive Alternatives | 2.3 ± 0.8 | 2.2 ± 1.1 |

*Note:* Sample sizes may differ slightly due to missing data. Physical Activity Self-Efficacy Scale scores: An answer of "yes" was scored as a 1, an answer of "no" was scored as 0. The maximal score for the Support Seeking subscale is 7. The maximal score for the Barriers Self-Efficacy subscale is 4. The maximal score for the Positive Alternatives subscale is 3.

Pedometer data were available for 38 of the program days. Participants were at the program and wore the pedometers for an average of 17.4 (± 1.8) minutes per day. Days where a participant achieved fewer than 15 steps per minute were removed from the data set. It was observed that when pedometers yielded abnormally low step counts, the pedometer may not have been completely upright, able to detect movement, and/or may have fallen off. This was observed by the researchers to happen fairly often. This led to the removal of 46 of a total of 875 data entries. Twenty-three of the removed numbers came from the same three participants who were overweight, and often the pedometer would not stay in a vertical position, which was needed for it to work properly.

Unadjusted step counts showed that participants took an average of 926 (± 404) steps per day at the program. After removal of low steps per minute counts, participants took an average of 987 (± 344) steps per day at the program. Adjusted steps per minute counts averaged 58.6 (± 20.8) steps per minute. Total average steps and steps per minute counts are presented in Table 2, and are divided into early intervention (first 13 pedometer data days), mid-intervention (second 12 pedometer data days), and late intervention (last 13 pedometer data days) to examine if children were similarly active throughout the program's duration. Repeated measures ANOVA were carried out to examine mean differences between early intervention, mid-intervention, and late intervention. Children took significantly more total steps ($p < .05$, $ES = 4.16$) and steps per minute ($p < .05$, $ES = 0.73$) during mid-intervention than early intervention, as well as significantly more total steps ($p < .05$, $ES = 4.44$) and steps per minute ($p < .05$, $ES = 1.01$) during late intervention than early intervention. On average, students took 208 steps per day and 9.1 steps per minute more during mid-intervention than early intervention and students took an average of 242 steps per day and 13.7 steps per minute more during late intervention than early intervention ($p < .05$). The total number of steps per day did not differ between mid-intervention and late intervention; however, when examining average steps per minute, students took an average of 4.6 steps per minute more in late intervention than in mid-intervention ($p < .05$, $ES$ = 0.28). Table 2 provides total steps and steps per minute means for early intervention, mid-intervention, and late intervention.

Table 2
Pedometer Step Counts and Steps per Minute at *First-Class*

| | Early Intervention 13 days | Mid-Intervention 12 days | Late Intervention 13 days |
|---|---|---|---|
| | *Mean* ± *SD* | *Mean* ± *SD* | *Mean* ± *SD* |
| Total Pedometer Steps | 868 ± 43 | 1,076 ± 57* | 1,110 ± 66* |
| Steps Per Minute | 50.9 ± 9.7 | 60.0 ± 15.3* | 64.6 ± 17.4*[t] |

*Note:* *significantly different ($p < .05$) from early intervention; [t]significantly different ($p < .05$) from mid-intervention.

Percent of time spent in sedentary behavior, and in light physical activity, moderate physical activity, vigorous physical activity, and total MVPA at the program each day. Two participants were completely excluded from the analysis of physical activity levels at the program. One participant's accelerometer stopped collecting data after 2 days, and collected abnormally low values for the days it did collect data. The other participant was excluded because the wear time log and accelerometer data did not match up on the same days, and it could not be verified that that participant was actually at the program on days where some activity was detected. Because participants did not attend the program for the same amount of time each day, percent of time spent, rather than total minutes in each activity were reported. During the week of accelerometer data collection, participants were at the program for an average of 18.8 (± 6.0) minutes per day. During their time at the program, participants spent about half of the time in sedentary behavior. Participants spent 22.1% (± 8.5%) of their time in moderate-to-vigorous physical activity, 12.7% (± 5.7%) of which was vigorous intensity physical activity.

Percent of time spent in sedentary behavior, light physical activity, moderate physical activity, vigorous physical activity, and total MVPA during the school day and average steps per minute for one week during and one week post-intervention are presented in Table 4.

School day physical activity measured by accelerometers was only collected for four days during the intervention because the accelerometers did not collect data for that Monday. School day physical activity post intervention was measured for five days (one whole week). Participants were excluded from the analysis if they did not have at least 3 days of valid data. A day was considered valid if the participant had at least 180 minutes of valid wear on that day. Wear-time validation was used in the ActiLife program to verify when participants were wearing accelerometers during the school day. Due to differences in total days, and wear time during the week during the intervention and the week post-intervention, total minutes spent in different activities cannot be compared. Rather, percent of time spent in each type of activity was used to compare school day physical activity during the intervention and post-intervention.

Participants, on average, spent slightly more time in sedentary behavior ($p < .05$, $ES$ = 0.33) during the school day post-intervention compared with days that students attended the intervention. Also, participants spent slightly less time in light physical activity ($p < .05$, $ES$ = -0.38), and took fewer steps per minute on average ($p < .05$, $ES$ = -0.40) during school days post-intervention than school days during the intervention. The difference between the percent of time spent in moderate physical activity (4.00 ± 0.95 minutes during intervention vs. 3.78 ± 0.81 minutes post-intervention) approached but did not reach significance ($p = .06$, $ES$= -0.26). No statistically significant differences in the percent of time spent in vigorous activity or percent of time spent in MVPA between school days during the intervention and school days post-intervention emerged. While the differences in moderate physical activity, vigorous physical activity, and percent of time in MVPA did not reach statistical significance, small to medium effect sizes were seen between post-intervention, when children did not attend the program, compared to intervention days, when students were at the program (moderate physical activity

*ES* = -0.24, vigorous physical activity *ES* = -0.23, and percent of time in MVPA *ES* = -0.25). Students were more active overall on school days with the intervention than on days without the intervention. The accelerometer data suggests that any physical activity accumulated during the program was extra physical activity, and children did not compensate by becoming less active during the school day on days they attended the program.

Table 3
Physical Activity at the Program Measured by Accelerometer

| | Tuesday<br>*n* = 19 | Wednesday<br>*n* = 22 | Thursday<br>*n* = 24 | Friday<br>*n* = 24 | Weighted Average |
|---|---|---|---|---|---|
| | *(Mean ± SD)* | *(Mean ± SD)* | *(Mean ± SD)* | *(Mean ± SD)* | *(Mean ± SD)* |
| Total Minutes | 20.8 ± 3.4 | 21.2 ± 6.0 | 20.0 ± 3.9 | 13.9 ± 6.6 | 18.8 ± 6.0 |
| % Sedentary | 69.5 ± 13.9 | 50.9 ± 11.8 | 50.4 ± 7.8 | 55.6 ± 12.9 | 56.0 ± 13.6 |
| % Light | 14.0 ± 5.8 | 24.1 ± 6.1 | 24.3 ± 4.7 | 23.7 ± 6.3 | 21.9 ± 7.0 |
| % Moderate | 6.1 ± 3.2 | 9.6 ± 4.4 | 11.0 ± 2.8 | 10.1 ± 4.6 | 9.4 ± 4.2 |
| % Vigorous | 10.4 ± 6.2 | 15.2 ± 5.7 | 14.2 ± 4.3 | 10.6 ± 5.2 | 12.7 ± 5.7 |
| % MVPA | 16.5 ± 8.9 | 24.9 ± 8.3 | 25.3 ± 5.6 | 20.7 ± 8.8 | 22.1 ± 8.5 |

*Note:* % Sedentary is percent of time spent in sedentary behavior; % Light is percent of time in light physical activity, % Moderate is percent of time in moderate physical activity, % Vigorous is percent of time in vigorous physical activity, % MVPA is the sum of the percent of time spent in both moderate and vigorous physical activity.

Table 4
Physical Activity during the School Day as Measured by Accelerometer

| | Intervention<br>*n* = 25<br>*(Mean ± SD)* | Post-Intervention<br>*n* = 25<br>*(Mean ± SD)* | *Effect Size* | *p* value |
|---|---|---|---|---|
| % Sedentary | 77.1 ± 4.9 | 78.6 ± 4.3 | 0.33 | .02 |
| % Light | 15.0 ± 3.0 | 13.9 ± 2.8 | -0.38 | .00 |
| % Moderate | 4.0 ± 0.9 | 3.8 ± 0.8 | -0.24 | .06 |
| % Vigorous | 4.0 ± 1.5 | 3.7 ± 1.1 | -0.23 | .10 |
| % MVPA | 8.0 ± 2.3 | 7.5 ± 1.7 | -0.25 | .10 |
| Steps per minute | 11.8 ± 2.7 | 10.8 ± 2.3 | -0.40 | .01 |

*Note:* % Sedentary is percent of time spent in sedentary behavior; % Light is percent of time in light physical activity, % Moderate is percent of time in moderate physical activity, % Vigorous is percent of time in vigorous physical activity, % MVPA is the sum of the percent of time spent in both moderate and vigorous physical activity, Steps per minute is average steps per minute taken at the during the school day.

Data from musculoskeletal fitness tests are shown in Table 5. No statistically significant differences or meaningful effect sizes between early and late intervention ($p < .05$) were found on upper body endurance, upper body power, or handgrip strength.

Table 5
Musculoskeletal Fitness Tests

| | Early Intervention $n = 24$ | Late Intervention $n = 24$ | |
|---|---|---|---|
| | *Mean ± SD* | *Mean ± SD* | *Effect Size* |
| Push-ups (# completed) | 3.7 ± 3.7 | 3.4 ± 4.2 | -0.08 |
| Seated Ball Toss (cm) | 230.0 ± 41.0 | 227.0 ± 42.0 | -0.07 |
| Handgrip Strength Right (kg) | 16.5 ± 4.5 | 16.7 ± 3.2 | 0.05 |
| Handgrip Strength Left (kg) | 15.9 ± 4.2 | 15.4 ± 2.9 | -0.14 |

Scores from the CogState assessment tasks are provided in Table 6. Results were similar when scores only of participants who were regular attendees of the *First-Class* program were analyzed and when scores of all participants with complete CogState data were analyzed. Data presented are only from those who were regular attendees at the program what completed the CogState assessment in both the no physical activity and physical activity conditions. Only eight participants were included in the One Back Task analysis. Due to a computer malfunction, seven participants took the Two Card Back Task rather than the One Back Task at either Session 1, Session 2, or both sessions, and therefore could not be included in the analysis. After running integrity checks recommended by CogState (2014) on the remaining 14 participants with both Session 1 and Session 2 data, six more participants were removed from the analysis due to accuracy levels of their performance below that recommended for a valid test.

As recommended by CogState, the main outcome variables analyzed were total errors for the Groton Maze Learning Task, reaction time for the One Back Task, and total errors for the Continuous Paired Associate Learning Task. The outcome of total errors was also included in the scoring of the One Back Task. While none of the differences in task errors reached significance, all effect sizes were small-to-medium. In all three tasks, participants made fewer errors on days that they engaged in at least 10 minutes of activity at the program, (Groton Maze Learning Task *ES* = -0.26; One Back Task *ES* = -0.27; Continuous Paired Associate Learning *ES* = -0.51) compared to days when they did not participate in physical activity before cognitive function testing. Reaction time did not differ between the no physical activity and physical activity conditions ($p$= .84; *ES*= 0.04).

Table 6
CogState Assessment Scores

| | Session 1- No Activity *(Mean ± SD)* | Session 2- 10 minutes and 750 Steps *(Mean ± SD)* | *n* | *Effect Size* | *p* value |
|---|---|---|---|---|---|
| Groton Maze Learning Task (Total Errors) | 99.95 ± 27.93 | 92.41 ± 29.91 | 22 | -0.26 | .16 |
| One Back Task (Total Errors) | 12.75 ± 8.91 | 10.50 ± 7.4 | 8 | -0.27 | .44 |
| One Back Task (Reaction Time) | 2.96 ± 0.18 | 2.95 ± 0.14 | 8 | -0.04 | .84 |
| Continuous Paired Associate Learning Task (Total Errors) | 87.65 ± 75.71 | 54.30 ± 55.45 | 20 | -0.51 | .06 |

*Note:* Total errors is the sum of all errors made over all trials in a given task. Lower score = better performance. Reaction time is the mean of the $\log_{10}$ of transformed reaction times for correct responses. Lower score = better performance. Sample sizes may vary, as integrity checks suggested by CogState that were conducted recommended deletion of some data that might be considered unreliable.

## Discussion

A review of the existing literature revealed that little research has examined before-school physical activity interventions. Programs implemented before the school day may increase daily physical activity, as children are often sedentary during this time. Also, any positive effects of an acute bout of physical activity would be beneficial at the beginning of the day, as improved cognitive function can help children learn. Therefore, the purpose of this study was to examine the effects the *First-Class* Before School Activity Program on physical activity levels during the program and school day, musculoskeletal fitness, and different domains of cognitive function.

### Physical Activity

In this study, physical activity at the *First-Class* Before School Activity Program (7:15 am- 7:45 am) was measured by pedometers daily and by accelerometers for one week during the program. Physical activity during the school day (7:45 am - 2:00 pm) was also measured for one week during the intervention and for one week post-intervention using accelerometers. At the program, participants took an average of almost 1,000 steps, as measured by pedometers. Because children arrived to the program at different times each day, their time-in and time-out were recorded to allow steps per minute to be calculated for each child, each day at the program. Participants were at the program for an average of 17. 4 (± 1.8) minutes per day. Pedometer data were also divided into early intervention, mid-intervention, and late intervention to determine if differences in activity level changed as the program continued. Participants took significantly fewer steps per day and steps per minute during early intervention than mid-intervention and late intervention. While no differences in the total step counts during the program were found between mid-intervention and late intervention, participants took more steps per minute during late intervention than mid-intervention. This suggests that a new physical activity intervention may continue to be successful in keeping children active, even after the novelty of the program may wear off.

In addition to the use of total steps and steps per minute as a measure of how children spent their time at the *First-Class* Before School Program, accelerometers were used to measure the percent of time spent in sedentary behavior, as well as light, moderate, and vigorous physical activity for one week (four days) during the program.

Accelerometer data were collected during a week that fell during the early part of the intervention. Participants took significantly fewer steps and steps per minute during early intervention than they did during mid-intervention and late intervention. When compared with other days during early intervention, participants were less active at the program on days when they wore an accelerometer. The mean steps per day during the 13 days of early intervention was 885 ± 457 steps. The mean steps per day measured by pedometers during the four days the accelerometer was worn was 684 ± 145 steps.

Despite the relatively low physical activity at the program during the week of accelerometer data collection, it can still be concluded that the physical activity of children in the *First-Class* Before School Program appears to be similar to the physical activity intensity of children observed in other times allotted for physical activity at school, such as physical education and recess. In a study where the intensity of children during physical education was assessed using direct observation, Nader (2003) reported that children spent 61.9 % of their time either sitting or standing without moving (sedentary behavior), a number slightly higher than what was observed in the present study. It was also observed that children spent about 11.9 minutes of each physical education session in MVPA, or about 34.6% of the time. Ridgers, Fairclough, and Stratton (2010) also used direct observation and reported the amount of time children spend in different activities during recess. On average, children spend between 21- 33% of their time during recess in MVPA. Only 4.5- 7.0% of that time is spent in vigorous physical activity. In the present study in which accelerometers were used to assess physical activity, children spent only 22.1% of their time in MVPA. In the studies by Nader and by Ridgers et al. in which direct observation was used to assess physical activity, any walking, regardless of speed, was considered moderate intensity activity. This may have led to an overestimation of time spent in MVPA. In addition, most of the MVPA in the current study was vigorous intensity physical activity, which differs from finding reported in other studies.

Prior to the start of the study, it was speculated that children who attended the program in the morning and had time to play might compensate during the school day, by being less active. It is a strength of this study that school day physical activity was assessed with accelerometers for one week while the program was in session, and for one week after the program ended. On days participants attended the program, they did not compensate by becoming less active during the school day, but rather participants spent significantly more time in sedentary behavior and significantly less time in light and moderate physical activity post-intervention. While no statistically significant differences in vigorous physical activity or total MVPA during the school day were noted between intervention and post-intervention, at all levels of activity the effect sizes between intervention and post-intervention school day physical activity were small-to-medium (*ES* = 0.23 - 0.38). Even when differences are not statistically significant, a small-to-medium effect size may be considered meaningful, given that attendance at a short program, under 20 minutes on average, before the school day was able to elicit differences. These small to medium sized differences may, over time, result in important changes. If an entire school day lasts approximately 6.5 hours, as in the current study, a before school program could decrease sedentary behavior each school week by an average of 29 minutes, and could increase total MVPA each week by an average of 10 minutes. Also, on days children attended the program they took 1 additional step per minute on average during the school day. Over time, this would equate to an additional 390 steps per day, and an additional 1,950 steps per school week, on average. These illustrated changes do not include time spent at the program, but only additional activity during the regular school day resulting from attendance at the before school program.

The *First-Class* Before School Program was held during a time that the children would have otherwise been sedentary. Children who were not in the program had to wait either on their bus or outside until the school day began, therefore, any physical activity accumulated during this time is more than they would have accumulated if the program was not in session. Children were in the program for an average of only 17 minutes per day, yet were able to accumulate an average of almost 1,000 steps during that time. Giving children the opportunity to be active before the school day may lead to an increase in total activity for that day. The idea that a before school program can lead to an increase in total daily physical activity is further supported by the accelerometer data which showed that, in this sample, children spent slightly less time in sedentary behavior and slightly more time in light, moderate, and vigorous physical activity, and total MVPA during the school day on days that they attended the program than on days they did not. In addition, participants took slightly more steps per minute on average during the school day on days they attended the program compared to days they did not attend the program.

It is important to note the limitations of the physical activity measurements in this study. The pedometers used in this study were secured with a metal clip to keep them attached to the child's waistband. These particular pedometers, however, must be upright in order for them to count steps, which was a limitation in this study and potentially led to a large amount of activity being undetected. Many of the activities the children did, such as push-ups, bear crawls, crab walks, or hula-hooping, may not have been picked up by these pedometers which only measure vertical hip displacement. Also, it was observed on certain occasions that despite a child doing vigorous activities, such as running or jumping rope, the pedometer did not add many steps. This happened most frequently with three of the children, who were overweight, and occasionally when children would wear dresses. When it was suspected that the pedometer was not picking up enough step counts, one of the researcher assistants checked the pedometer periodically. One child had abnormally low step counts for 10 of 34 attended days, and another child on 8 of 34 attended days. Despite observing the child being active, the pedometer in some instances recorded step counts as low as < 1 step per minute. For these children, the pedometer would not remain upright in the correct wear location. In an attempt to fix this problem and keep the pedometer upright, researchers would move the pedometer to these children's right side closer to their back.

It is also a limitation of this study that only physical activity during the school day was measured, and therefore any compensatory changes in physical activity levels outside of the school day that may have occurred could not be measured. Future studies should measure physical activity continuously throughout the day or week to assess whether or not children compensate and decrease their physical activity levels after a program such as this one.

**Musculoskeletal Fitness**

In this study, a before-school physical activity program that included upper body strengthening activities about 3 days per week did not elicit any changes in upper body endurance, power, or handgrip strength. This, however, could be because when activities using upper body strength were included on a given day, it was during the 10-minute, structured activity portion of the program, and a short, 10-minute activity 3 days per week may not have been enough to elicit changes in upper body strength or power.

It is a limitation of this study that while researchers were trained on how to administer each test, some researchers may not have been as strict as others in scoring the push-up and seated ball-toss tests, thus interfering with the integrity of the test. It was observed in some instances that researchers were counting test attempts or certain repetitions that were not completed correctly with good form. Additionally, participants were required to show good form during the ball toss, and even after practice, sometimes failed to show proper form during the scored ball tosses. In the protocol used in this study, the children were required to repeat the test until two trials were shown with good form. It was noted later that during this time, fatigue may have resulted, affecting the measurement of the seated ball toss and its integrity as a maximal power assessment.

In addition to the limited amount of time for muscle- and bone-strengthening activities, time spent at the program was limited by factors out of the control of the researchers, such as when participants arrived at school. Almost all of the children arrived to school on buses, and therefore when they got to the program depended on when their bus arrived. On certain days buses may have been late, and students on that bus could not attend the program for more than a few minutes or sometimes not at all on that day. For the few children who arrived via car or with a parent, on certain days some reported that their parent or guardian would not be ready early enough for them to attend the program for as long as they would have liked to each day.

**Cognitive Function**

In this study, a 10-minute bout of physical activity at the *First-Class* Before School Program was associated with fewer errors during all three cognitive function assessments. Participation in short bouts of physical activity improves attention-to-task (Mahar et al., 2006), which may partially explain why participants in the present study made fewer errors on all three tasks on days that they were physically active before cognitive function tests.

Reaction time is another outcome variable assessed with the One Back Task. Although participants made fewer errors during the One Bask Task, reaction time did not change. However, it has been suggested in that reaction time may not be an accurate assessment of cognitive function in children, as children tend to be more impulsive than adults (Hillman et al., 2009).

Chaddock et al. (2010) found that high-fit children had a quicker reaction time on cognitive function assessments than low-fit children. In the current study, the focus was on the effect of acute bouts of physical on cognitive function, rather than fitness levels. Hillman et al. (2009) examined the effect of acute treadmill walking on cognitive control in preadolescent children and found no relationship between reaction time and the exercise, and reported that this was due to likely impulsivity of children. These findings are similar to those of the current study.

Study limitations include lack of a control group and timing of the CogState assessments. All of the no-activity condition CogState assessments were taken near the beginning of the program, while all of the physical activity condition CogState assessments were taken near the end of the program. Without a control group, it cannot be determined whether adaptations from engaging in regular physical activity at the program, independent of adaptations in fitness that may have occurred, could have improved cognitive function. Therefore, it is possible that those who regularly attended the program improved their cognitive function from regular physical activity, and not necessarily from the acute bout of physical activity engaged in before the physical activity condition. It is also possible that cognitive function could have improved from the children getting older and being in school for longer than they had been during the first CogState session at the beginning of the intervention. A counterbalanced design, where half of the children took the CogState assessments after a physical activity bout at the beginning of the program and the other half at the end of the program would have addressed this limitation. Without a control group or without having a counterbalanced design, these possibilities cannot be ruled out.

The CogState assessment system has been used frequently with adults to assess various domains of cognitive function. Limited psychometric evidence of reliability and validity of Cogstate for use with children is available. Care was taken, however, to ensure tasks were chosen that were recommended for this age group by CogState (2014). Prior to assessments, research assistants practiced administering the tests to children.

**Physical Activity Self-Efficacy**

The questionnaires used to assess the psychological variables of physical activity enjoyment and physical activity self-efficacy have been recommended for this age group. Children’s self-efficacy for physical activity may be an important indicator of whether or not they are likely to engage in physical activity on their own, and may impact whether children are interested in attending an activity program, such as the one offered in the current study. In the current study, children seemed to understand the modified Physical Activity Self-Efficacy Scale. The modified version of this scale, which only uses yes/no answers, was chosen for its simplicity. Saunders et al. (2007) stated that while reduction from a 5-point scale to a dichotomous yes/no scale sacrifices variance, the simplification may be necessary to obtain meaningful self-report data from pre-adolescent populations. Of the 24 participants who were regular participants of the program and completed the Physical Activity Self-Efficacy Scale, only two did not complete a question. Because subscales are scored separately, it was decided to include the data for these two children in the subscales for which complete data were available, but to exclude their data in subscales for which they had missing data. The descriptive data from this questionnaire can be used to describe the barriers to physical activity perceived by this particular sample. Girls perceived themselves to have less support from others for physical activity and perceived more barriers than males. While the difference did not reach statistical significance, likely due to the small sample size, the size of the difference between the two groups was small to medium (Support Seeking *ES* = 0.57; Barriers *ES* = 0.31).

Trost et al. (1997) reported their sample of girls had slightly higher scores on the support-seeking subscale (6.4 ± 1.1 vs. 5.7 ± 1.5) and about the same average score on the barriers self-efficacy subscale (2.4 ± 1.4 vs. 2.6 ± 1.3) as the girls in the current study. The boys in the study by Trost et al. had similar support seeking subscale scores (6.2 ± 1.1 vs. 6.3 ± 0.8) and slightly lower barriers self-efficacy scores (2.6 ± 1.2 vs. 3.0 ± 1.2) compared to boys in the current study. Some of the items on the positive alternatives subscale used by Trost et al. were omitted in the modified version (Saunders et al., 1997) that was used in the current study. Therefore, total positive alternative subscale scores cannot be compared between studies.

Research has suggested that children who perceive fewer barriers to physical activity are more likely to engage in physical activity than those who perceive more barriers to physical activity (Hearst et al., 2012), and are therefore more likely to meet physical activity recommendations. While the impact of the before school program on physical activity self-efficacy was not assessed in this study, the program addressed some of the barriers to physical activity assessed by the Physical Activity Self-Efficacy Scale, such as not having friends to be active with, lacking knowledge about physical activity, or lacking skills for physical activity. Prior research suggests that participation in a physical activity program may increase physical activity self-efficacy (Annesi, 2005; Sung, Yu, So, Lam, & Hau, 2004).

The third graders sampled for this intervention were from eastern North Carolina, and of the 39 children who attended the program at least one time, 85% were either African American or Latino. Of the 28 children who regularly attended the program, 89% were African American or Latino. Of the children with weight and height data, 40% of girls and 36% of boys were classified as overweight or obese according to age- and gender-specific BMI percentiles, which is higher than the national average of about 18.5% (Ogden et al., 2012). The diversity of this sample is representative of the school from which the sample was selected, though the sample may not represent all third grade students in the country. Also, many of the participants were of low socioeconomic status. Most of the regular attendees of the program received their breakfast at school each day from the free or reduced-price program. The need for participants to eat breakfast at school resulted in the program being 5 minutes shorter than what was initially planned. Finally, in observing the children during the CogState assessments and in speaking with their teachers, many of the children in the current sample may not have had the reading comprehension or other academic skills of average third graders, and the tests may have been too difficult for some of the students to understand. For these reasons, conclusions from the current study may not be generalizable to other elementary populations.

**Recommended Future Directions**

Physical activity was assessed in this study using pedometers daily at the program and accelerometers for one week during and one week after the program. Given the nature of this particular program and that several activities were not traditional aerobic activities or activities that would elicit large changes in hip displacement or acceleration, an alternative method to measure physical activity may provide more accurate measures of physical activity. The pedometers used in this program only measure vertical hip displacement, which may not accurately pick up several of the activities performed, such as hula hooping, crawling, or resistance exercises. Accelerometers are useful for measuring the quantity and quality of normal, ambulatory movement, and may not be the best measurement of physical activity intensity when alternative activities are being performed. Perhaps a heart rate monitor and/or a direct observation method may be more suitable for such activities. Furthermore, regarding compensatory physical activity, conclusions in this study cannot be made regarding time spent outside the school day. Future studies should measure physical activity outside of the school day to ensure that children who have the opportunity to be active in a before school program, such as in the current study, do not compensate after school and decrease activity. Conversely, it may be of interest to determine if children who engage in activity before school are more likely to also engage in physical activity after school.

Programs in the future should also attempt to examine whether a dose-response exists between physical activity time and intensity and acute changes in cognitive performance. In the current study, a threshold of 10 minutes at the program and an accumulation of 750 or more pedometer steps was used to indicate the physical activity condition before cognitive function testing. Because the type and intensity of activity accumulated by children may have varied greatly during this time, no conclusions can be made about types and/or intensities of activities and their relationship with cognitive function. Additionally, it is important to determine the length of time that an acute bout of physical activity has on cognitive function, if such an effect exists. Future studies may also examine differences in resistance activities and traditional aerobic activities and their acute effects on cognitive function.

Additional research may seek to determine how changes that may result from acute bouts of physical activity before or during school can impact performance in the classroom. It is important to provide evidence that physical activity is beneficial and may enhance the school environment in the hope of motivating policy makers to create a more activity friendly school environment.

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# Appendix

**EAST CAROLINA UNIVERSITY**
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## Notification of Continuing Review Approval: Expedited

From: Biomedical IRB
To: Matthew Mahar
CC:
Date: 8/22/2014
Re: CR00002239
UMCIRB 13-001781
Effects of a Before-School Activity Program on School Day Physical Activity and Cognitive Function

The continuing review of your expedited study was approved. Approval of the study and any consent form(s) is for the period of 8/22/2014 to 8/21/2015. This research study is eligible for review under expedited category #4. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

| Document | Description |
|---|---|
| Consent Form(0.02) | Consent Forms |
| First-Class Recruitment Letter 2013.docx(0.01) | Recruitment Documents/Scripts |
| PACES(0.01) | Interview/Focus Group Scripts/Questions |
| Physical Activity Enjoyment Scale - PACES (1).doc(0.01) | Surveys and Questionnaires |
| Physical Activity Self-Efficacy Scale(0.01) | Interview/Focus Group Scripts/Questions |
| Physical Activity Self-efficacy Scale (1).doc(0.01) | Surveys and Questionnaires |
| Script to Obtain Child Assent(0.01) | Consent Forms |
| Study Protocol(0.01) | Study Protocol or Grant Application |

The Chairperson (or designee) does not have a potential for conflict of interest on this study.